60
A90A
57

PROCEEDINGS

OF THE

FIFTY-FIFTH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

Construction and Maintenance Section, Engineering Division
Association of American Railroads

HELD AT THE

PALMER HOUSE, CHICAGO, ILLINOIS

March 13, 14 and 15, 1956

VOLUME 57

This volume, as listed in the Table of Contents, includes all the committee reports, reports on research projects, monographs, and memoirs originally published in AREA Bulletins 523 to 528, incl., June–July 1955 to February 1956.

Copyright, 1956, by
AMERICAN RAILWAY ENGINEERING ASSOCIATION
59 East Van Buren Street
Chicago, 5, Illinois

OFFICERS, 1955-1956

G. M. O'Rourke
President

Wm. J. Hedley
1st Vice President

Ray McBrian
2nd Vice President

C. G. Grove
Past President

G. W. Miller
Past President

A. B. Hillman
Treasurer

Neal D. Howard
Executive Secretary

DIRECTORS

E. S. Birkenwald
1953–56

H. B. Christianson
1953–56

B. R. Meyers
1953–56

G. E. Robinson
1953–56

C. B. Porter
1954–57

C. H. Sandberg
1954–57

W. H. Giles
1954–57

H. R. Peterson
1954–57

E. J. Brown
1955–58

F. R. Woolford
1955–58

R. H. Beeder
1955–58

C. J. Code
1955–58

BOARD OF DIRECTION

President

G. M. O'Rourke, Assistant Engineer Maintenance of Way, Illinois Central Railroad, Chicago 5.

Vice Presidents

Wm. J. Hedley, Assistant Chief Engineer, Wabash Railroad, St. Louis 1, Mo.

Ray McBrian, Engineer Standards and Research, Denver & Rio Grande Western Railroad, Denver 1, Colo.

Past Presidents

C. G. Grove, Area Engineer, Pennsylvania Railroad, Chicago 6.

G. W. Miller, Engineer Maintenance of Way, Eastern Region, Canadian Pacific Railway, Toronto 1, Ont.

Directors

E. S. Birkenwald, Engineer Bridges, Western Lines, Southern Railway System, Cincinnati 2, Ohio

H. B. Christianson, Special Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago 6.

B. R. Meyers, Chief Engineer, Chicago & North Western System, Chicago 6.

G. E. Robinson, Engineer of Structures, Lines West of Buffalo, New York Central System, Chicago 5.

C. B. Porter, Assistant to Vice President, Construction and Maintenance, Chesapeake & Ohio Railway, Richmond 10, Va.

C. H. Sandberg, Assistant Bridge Engineer System, Atchison, Topeka & Santa Fe Railway, Chicago 4.

W. H. Giles, Assistant Chief Engineer System—Construction, Missouri Pacific Lines, St. Louis 3, Mo.

H. R. Peterson, Chief Engineer, Northern Pacific Railway, St. Paul 1, Minn.

E. J. Brown, Chief Engineer, Burlington Lines, Chicago 6.

F. R. Woolford, Chief Engineer, Western Pacific Railroad, San Francisco 5, Calif.

R. H. Beeder, Assistant Chief Engineer System, Atchison, Topeka & Santa Fe Railway, Chicago 4.

C. J. Code, Assistant Chief Engineer—Tests, Pennsylvania Railroad, Philadelphia, 4, Pa.

Treasurer

A. B. Hillman, Chief Engineer, Belt Railway of Chicago; Chicago & Western Indiana Railroad, Chicago 5, Ill.

Executive Secretary

Neal D. Howard, 59 East Van Buren St., Chicago 5.

Assistant Secretary

E. G. Gehrke, 59 East Van Buren St., Chicago 5.

Secretary Emeritus

Walter S. Lacher, 407 East Fuller Road, Hinsdale, Ill.

NUMERICAL INDEX TO COMMITTEE REPORTS

	Report	Discussion
1—Roadway and Ballast	643	1077
3—Ties	441	1055
4—Rail	783	1086
5—Track	683	1066
6—Buildings	381	1023
7—Wood Bridges and Trestles	565	977
8—Masonry	529	996
9—Highways	325	952
11—Records and Accounts	579	922
13—Water, Oil and Sanitation Services	335	963
14—Yards and Terminals	363	928
15—Iron and Steel Structures	553	998
16—Economics of Railway Location and Operation	313	944
17—Wood Preservation	443	1019
20—Contract Forms	347	920
22—Economics of Railway Labor	397	1044
24—Cooperative Relations with Universities	571	969
25—Waterways and Harbors	377	949
27—Maintenance of Way Work Equipment	473	1037
28—Clearances	547	991
29—Waterproofing	437	1017
30—Impact and Bridge Stresses	433	993
Special Committee on Continuous Welded Rail	775	1054

TABLE OF CONTENTS

Page

Chemical Cleaning and Painting of Railroad Bridges, by Dr. Joseph Bigos. Advance Report of Committee 15—Iron and Steel Structures 1

Tests of Steel Girder Spans on the Milwaukee Railroad. Advance Report of Committee 30—Impact and Bridge Stresses 15

Tie Renewals and Costs Per Mile of Maintained Track. Advance Report of Committee 3—Ties 173

An Investigation of Fatigue Failures in Structural Members of Ore Bridges Under Service Loadings, by L. T. Wyly and M. B. Scott, assisted by A. L. Flassig, Jr., J. F. Ely, H. L. Leve, Z. L. Moh, and H. C. Prince. Advance Report of Committee 15—Iron and Steel Structures 175

Report on Joint Metallurgical Societies Meeting in Europe—1955, by R. E. Cramer . 299

Rail Corrugation—Can It Be Prevented? By C. H. Spaderna 307

Reports of Committees on

Economics of Railway Location and Operation 313

Revision of Yager Formula 314

Economics of "Highway Trailers on Flat Cars" Service 314

Comparison of Running Time with Total Time Between Loading and Unloading Points of Freight Cars, and Method of Reducing Total Time 321

Discussion 944

Highways 325

Merits and Economics of Metal Grating Type Crossings 326

Outline to Guide Highway Departments and Others in Making Applications for Easements, Etc. 327

Standard Stop Sign for Use by Crossing Watchmen 329

Problems Related to Location and Construction of Limited Access Highways in Vicinity of or Crossing Railways 331

Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railways 331

The Effect of Highway Improvement Projects on Railway Properties 333

Discussion 952

Page

Water, Oil and Sanitation Services 335

Federal and State Regulations Pertaining to Railway Sanitation 336

Cathodic Protection of Pipe Lines and Steel Storage Tanks 337

New Developments in Water Conditioning for Diesel Cooling Systems 337

Railway Waste Disposal 338

Treatment of Water For Cooling Purposes 339

Diesel Oil and Water Servicing Facilities 342

Detection and Diesel of Radioactive Materials in Air, Oil and Water Filters on Diesel Locomotives and Other Equipment 344

Sterilization of New and Repaired Water Wells, Pipe Lines and Other Equipment Used in Handling Drinking Water 344

Discussion 963

Contract Forms 347

Revision of Manual 348

Form of Lease Covering Subsurface Rights to Mine Under Railway Miscellaneous Physical Property 350

Insurance Provisions Recommended for Various Forms of Agreements 350

Form of Agreement for Turnpike or Toll Road Crossing Railway Tracks and Property 355

Discussion 920

Yards and Terminals 363

Revision of Manual 364

Classification Yards 365

Scales Used in Railway Service 369

Part 1—Specifications for the Manufacture and Installation of Four-Section Motor Truck Scales 369

Part 2—Weighing Freight Cars by the Two-Draft Method 369

Part 3—Electronic Scales 370

Waterfront Terminals 370

Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars . 373

Location and Design of Car Repair Tracks and Facilities in Relation to Classification Yards 374

Location and Design of Engine Servicing Tracks and Facilities in Relation to Classification Yards 375

Discussion 928

Page

Waterways and Harbors 377

Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation 377

Discussion 949

Buildings 381

Shop Facilities for Diesel Locomotives 382

Discussion 1023

Economics of Railway Labor 397

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work 398

Comparative Economy of Routine Track Maintenance with Limited Size Forces, and Cycle, Out-of-Face Track Maintenance with Fully Mechanized Forces 417

Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization 423

Comparative Economy of Handling Maintenance of Way Gangs in Trucks Versus Motor Cars, Including Economical Length of Haul 424

Economic Size of Maintenance Force Using On or Off-Track Tampers and Renewing an Average of 100 Ties per Mile 430

Discussion 1044

Impact and Bridge Stresses 433

Steel Girder Spans with Open Decks and with Ballasted Decks 434

Dynamic Shear in Girder and Truss Spans 434

Concrete Structures 434

Stresses and Impacts in Timber Stringer Bridges 435

Steel Truss Spans with Open Decks and with Ballasted Decks 435

Stresses in Lateral Bracing of Bridges 435

Discussion 993

Waterproofing 437

Waterproofing Materials and Their Application to Railway Structures 438

Waterproofing Coatings to Prevent Concrete Deterioration 439

Discussion 1017

Ties 441

Discussion 1055

Page

Wood Preservation 443

Revision of Manual 444

Service Test Records of Treated Wood 446

Destruction by Marine Organisms; Method of Prevention 457

Destruction by Termites; Methods of Prevention 464

New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products 464

Effect of AREA Standards and Specifications of Any Changes in Manufacturing Processes and Specifications for Creosote, Petroleum and Other Products 465

Treatment of Wood to Make It Fire Resistant 468

Treatment of Laminated Timbers 471

Discussion 1019

Maintenance of Way Work Equipment 473

New Developments in Work Equipment 474

Improvements to Be Made to Existing Work Equipment 488

Pneumatic Tires and Tubes 490

Storage Batteries 496

Devices for Warning Forces of Approaching Trains 504

Care and Operation of Work Equipment in Freezing Weather 505

Track Lining Equipment 514

Additional Types of Work Equipment Desired 518

Off-Track Trailers for Housing Maintenance Forces 519

Discussion 1037

Masonry 520

Principles of Design of Masonry Structures, Including Design of Masonry Culverts 531

Methods for Improving the Quality of Concrete and Mortars 539

Discussion 996

Clearances 547

Compilation of the Railroad Clearance Requirements of the Various States 548

Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection 549

Discussion 991

Iron and Steel Structures 553

Revision of Manual 554

Stress Distribution in Bridge Frames 556

Page

Preparation and Painting of Steel Surfaces 556

Substitutes for Paints for Preservation of Steel Bridge Structures 557

Economics of Various Design Loadings 558

Discussion 998

Wood Bridges and Trestles 565

Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints 566

Design of Timber–Concrete Composite Decks 569

Means of Conserving Labor and Materials, Including the Adaptation of Substitute Noncritical Materials, and Specifications for the Reclamation of Released Materials, Tools and Equipment 570

Discussion 977

Cooperative Relations with Universities 571

Stimulate Among College and University Students A Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure, By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities 572

The Cooperative System of Education, Including Summer Employment in Railway Service 574

The Fiftieth Anniversary of Cooperative Engineering Education, by Ovid W. Eshbach 574

Conduct a Study Looking to the Publication of a Booklet, or Booklets, for Distribution to Educational Groups, Particularly High Schools and Undergraduates in Colleges, Designed to Stimulate Interest in the Opportunities Afforded in a Railroad Engineering Career 577

Discussion 969

Records and Accounts 579

Revision of Manual 582

Bibliography on Subjects Pertaining to Records and Accounts 582

Office and Drafting Practices 595

Use of Statistics in Railway Engineering 599

Construction Reports and Property Records 620

Valuation and Depreciation 638

Revisions and Interpretations of ICC Accounting Classifications 641

Discussion 922

Page

Roadway and Ballast 643

Culverts:
(b) Specifications for High-Pressure Gas Lines 645

Roadway: Formation and Protection 648

Part 1—Relocation of Railroad Embankment O'Hare Field, Chicago, by Ralph B. Peck 649

Part 2—Stabilization By Electro-Osmosis, by Ralph B. Peck 658

Tunnels 660

Ballast 661

Third Progress Report on Research Project on Ballasts 661

Chemical Control of Vegetation 662

Part 1—Fifth Annual Report on AAR Cooperative Weed Control Project, by W. E. Loomis, E. G. Rodgers, L. O. Baker, and R. H. Schieferstein 662

Part 2—Chemical Control of Vegetation—1955 AAR Report 670

Discussion 1077

Track 683

Track Tools 685

Plans for Switches, Frogs, Crossings, Spring and Slip Switches 686

Appendix 3-a—Service Tests of Solid and Manganese Steel Insert Crossings at McCook, Ill. 687

Appendix 3-b—Service Tests of Solid and Manganese Steel Insert Crossings Supported by Steel T-Beams and Longitudinal Timbers 689

Prevention of Damage from Brine Drippings on Track and Structures 696

Design of Tie Plates 700

Hold-Down Fastenings for Tie-Plates, Including Pads Under Plates; Their Effect on Tie Wear 707

Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings 735

Part 1—Service Tests on the Illinois Central 736

Part 2—Laboratory Brine Corrosion Tests of Metal Preservatives Used in Rail Joints 757

Laying Rail Tight with Frozen Joints 760

Critical Review of the Subject of Speed on Curves and Turnouts as Affected by Present-Day Equipment 764

Methods of Heat Treatment, Including Flame Hardening, of Bolted Rail Frogs and Split Switches, Together with Methods of Repair by Welding 768

Discussion 1066

Page

Continuous Welded Rail 775

Fabrication 776

Discussion 1054

Rail 783

Revision of Manual 784

Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest 787

Appendix 2–a—Investigation of Failures in Control Cooled Railroad Rails, by R. E. Cramer 787

Rail Failure Statistics, Covering (a) All Failures; (b) Transverse Fissures; (c) Performance of Control-Cooled Rail 794

Rail End Batter: Causes and Remedies 814

Economic Value of Various Sizes of Rail 815

Service Tests of Various Types of Joint Bars 817

Joint Bar Wear and Failures; Revision of Design and Specifications For New Bars, Including Insulated Joints and Bars For Maintenance and Repairs ... 817

Appendix 7–a—Fourteenth Progress Report of the Rolling-Load Tests of Joint Bars, by R. S. Jensen 818

Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention 830

Appendix 8–a—Fourteenth Progress Report on Shelly Rail Studies at the University of Illinois, by R. E. Cramer 850

Recent Developments Affecting Rail Sections 858

Service Performance and Economics of 78-Ft Rail; Specifications for 78-Ft Rail 859

Appendix 10–a—Joint Gap Measurements 860

Appendix 10–b—Tests of Rail Joint Impact Effects on the Chicago & North Western 865

Rail Damage Resulting from Engine Burns; Prevalence; Means of Prevention; Repair by Welding 883

Discussion 1086

PROCEEDINGS

Program 887

Report of the Tellers 890

Opening Session 891

Address by President G. M. O'Rourke 893

Report of Executive Secretary Neal D. Howard 898

Page

Report of Treasurer A. B. Hillman 899

Greeting from Signal Section, AAR, by A. L. Essman 900

Greeting from Electrical Section, AAR, by K. H. Gordon 901

Address: Fair Treatment for All, by Richard G. May 903

Address: Building People, by Harvey C. Marmaduke 906

Address: Engineering for Mobility, by Major Gen. Chas. G. Holle 914

Discussion of Committee Reports (see preceeding pages of the Table of Contents)
Annual Luncheon Address, by Wayne A. Johnston 1002

Closing Business 1094

Addresses Presented in Conjunction with Committee Reports:

Electronic Weighing of Freight Cars in Motion, by Verne C. Kennedy 932

Summary of Report Prepared by the AAR Calumet Sag Committee in Opposition to the Calumet Sag Navigation Project, by A. L. Sams 949

Statement Respecting Proposed Highway Legislation, by H. H. Hale 960

Panel Discussion on How Can the Railroads Attract and Hold an Adequate Number of Qualified Engineering Graduates in Competition with Other Industries, by C. C. Grove, G. H. Echols, D. W. Tilman, R. P. Davis, O. W. Eshbach 971

Development of Working Stresses for Glued Laminated Lumber, by Alan D. Freas 979

Use of Structural Glued Laminated Lumber by Railroads, by Frank J. Hanrahan 986

Structural Damage Caused by Hurricane Diane, by W. R. Wilson 1009

Painting Frame Buildings, by Don F. Laughnan 1025

Better Human Relations as a Key to Improving Maintenance of Way Work, by W. E. Cornell 1051

Cooperative Research on Cross Ties between NLMA and AAR, by G. M. Magee 1057

Panel Discussion on Cross Ties, by L. C. Collister, H. R. Duncan, L. W. Kistler, P. D. Brentlinger, C. S. Burt, L. P. Drew 1059

Highlights of Work Performed by Committee 5—Track, by C. J. Geyer 1073

Landslides and Their Significance to Engineers, by Edwin B. Eckel 1081

Investigation of Failures in Control-Cooled Railroad Rails, by R. E. Cramer ...1088

Tests of Rail Joint Impact Effects, by G. M. Magee 1089

Rail Failure Statistics, by G. M. Magee 1091

MEMOIRS

Page

T. L. Condron 530

Cornelius Jacoby 580

A. H. Meyers 581

J. W. Hopkins 684

O. W. Stephens 1023

H. C. Archibald 1044

G. W. Harris 1087

L. C. Fritch 1101

Report of the Executive Secretary 1105

Report of the Treasurer 1120

Constitution 1121

Information for Committees 1132

Advance Report of Committee 15—Iron and Steel Structures

A. R. Harris, *Chairman*

Chemical Cleaning and Painting of Railroad Bridges

By Dr. Joseph Bigos

Director of Research, Steel Structures Painting Council

In Collaboration With Research Staff

Association of American Railroads

A. DIGEST

For the past three years the AAR research staff has been cooperating with the Steel Structures Painting Council to determine the suitability—for painting—of chemically cleaned and pretreated surfaces in comparison with surfaces cleaned by hand-chipping and wire-brushing methods, and to evaluate the performance of a number of paints and coatings. For this investigation portions of two through-plate girders of a railroad bridge in Chicago (see Fig. 1) were first chemically cleaned by use of a "flush-off" paint stripper and steam, and then pretreated with a proprietary cold phosphate rust remover. Other portions were cleaned by hand chipping and wire brushing. Six primers were applied to both types of cleaned surfaces, and one-half of each primed surface was top coated with a black finish paint. A detailed inspection was held on June 29, 1954.

The chemically cleaned and pretreated surfaces were inferior to the hand cleaned surfaces, but a chemically cleaned surface without the pretreatment was slightly superior to a similar hand-cleaned surface. The best primers were Paint No. 1 and Paint No. 2 (See Fig. 7). Some of the primers were very poor. Asphalt oil (Paint No. 7) when later top-coated with asphalt bridge cement (Paint No. 8) and a grease compound (Paint No. 9) gave almost complete protection to hand-cleaned surfaces. But no paint or coating was satisfactory over very heavy rust scale.

B. OBJECT

The primary object of this field paint test was to determine the suitability—for painting—of a chemically cleaned and pretreated surface in comparison with a surface cleaned by the usual hand-chipping and wire-brushing method. A secondary purpose of this test was to evaluate the comparative performance of a number of paints and coatings.

C. DESCRIPTION OF TEST

The field paint test was conducted on the top flange and the west face of a through-plate girder railroad bridge adjacent to the Research Center of the Association of American Railroads in Chicago. The inside of two plate girders, above the floor line, and the top flange were cleaned and painted, as shown on Figs. 2 and 3. Details of the cleaning methods and paints used are also noted on these figures.

Surface Preparation

On June 12, 1951, representatives of a manufacturer of a "flush-off" type of chemical paint remover used their product to remove the old paint from panels 1 to 4, incl., as shown on Fig. 2. Following the stripping of the paint, a cold phosphate pretreatment supposed to be a rust remover, was applied to panels 1 to 3, incl., and the surface rinsed off with hot water after drying. Panels 5 to 9, incl., were chipped by hand and wire brushed in the usual manner by painters from a railroad; no attempt was made to remove the old adherent paint. The bridge was a ballasted-deck type, and the bottom of the panels in contact with the ballast remained moist, resulting in a band of very heavy rust scale about 6 in high adjacent to the floor line.

In addition to the cold phosphate pretreatment applied to the three panels which were chemically cleaned, another proprietary rust removing pretreatment—containing selenium—was applied to the right half of panel 5, which had been hand cleaned. Portions of the top flange and west face of a second girder, as shown in Fig. 3, had been cleaned at various times by hand chipping and wire brushing.

Paints

The six paint primers tested on girder 1 were: Paint No. 1, a paint equivalent to Steel Structures Painting Council Paint No. 2, containing 75 percent red lead and 25 percent iron oxide in the pigment, and 2 parts of linseed oil to 1 part of alkyd solids in the vehicle, and weighing about 22 lb per gal; Paint No. 2, a red lead paint (railroad company's formula), containing pure red lead as the pigment and a mixture of raw and bodied linseed oil as the vehicle, complying with Federal Specification TT–P–86a, Type I, and weighing 24 lb per gal; Paint No. 3, a state highway department red lead paint, a primer supposedly complying to the same composition requirements as Paint No. 2, but the paint that was applied did not have the viscosity required for proper application and, as a result, was applied at about one-half the thickness, or twice the coverage, as the other paints; Paint No. 4, a paint containing some rust-inhibitive pigment and iron oxide in the pigment and a vehicle based upon processed fish oil; Paint No. 5, another proprietary paint for rusty surfaces, the composition of which is unknown; and Paint No. 6, an extended red lead, semi-quick-drying paint.

These primers were tested by coating panels or portions of panels of the girder as shown on Fig. 2. For example, the left half of panel 1, marked 1 La and 1 Lb, was primed with Paint No. 1. The primers were applied during the months of June and July 1951.

To test the performance of the primers under a top coat as part of a complete paint system, one-half of each primed portion was painted with a top coat of Paint No. 10, which consists of carbon black pigment and a vehicle containing gilsonite-linseed oil varnish, raw linseed oil and japan drier. The primers were applied to the chemically cleaned and pretreated surfaces as well as to the hand-cleaned surfaces. In addition, Paint No. 1 was tested over the proprietary cold phosphate pretreatment containing selenium on the hand-cleaned steel of the right half of panel 5 as compared with the

left half of panel 5, which did not have any pretreatment. Paint No. 1 was also tested on panel 4, which was treated chemically to remove the old paint, but which did not receive any pretreatment afterwards. This panel, incidentally, was not cleaned as effectively as the first three because cold water was used to remove the flush-off paint remover in a first and unsuccessful attempt at cleaning on April 18, 1951.

Application

All paints were applied in a consistent manner under recorded conditions by railroad painters and were applied by brush. The most important feature of the application was the coverage or dry film thickness of the paint. All paints were put on with as thick a coverage as possible and were applied in a thorough manner. The paints were weighed before and after application and the following coverages were obtained.

PAINT COVERAGES

	Chemically Cleaned and Pretreated		*Hand Cleaned*		
	Panel No.	*Coverage Sq Ft/Gal*	*Panel*	*Cov.*	*Average Cov. Sq Ft/Gal*
No. 1	1L	285	5L	280	285
No. 1	(on hand cleaned and pretreated)		5R	300	300
No. 2	1R	no data	8R	350	350
No. 4	2L	335	6L	290	315
No. 5	2R	315	6R	270	295
No. 3	3L	525	7L	800	665
No. 6	3R	340	7R	395	370

An attempt was made to measure the dry film thickness of the paints, but the measurements were inaccurate and inconsistent because of the old paint, rust and scale on the surface; as a result, it was impossible to obtain a satisfactory zero point for the film thickness meter. The measurements that were made indicated that the primers were in the region of 1½ to 2½ mils in thickness, and the top coat ran about 1 to 1½ mils in thickness. Because of the high volatile content of some of the proprietary paints, their dry film thickness runs much lower than the high-solids paints at equal coverages.

In addition to the paints tested in the main portion of this test, several other materials were used. The left half of panel 8 was hand cleaned and coated with Paint No. 7 —an asphalt oil. This part was allowed to dry, and on September 7, 1951, the left half of this part was coated with an asphalt cement, Paint No. 8. Panel 9 was treated with a heavy coating of Paint No. 9, which was applied at a thickness of about $\frac{1}{16}$ in. This material is a grease type of rust-proofing compound.

A number of proprietary products were applied to the top flange and to the west face of girder 2 (see Fig. 3), including Paint No. 8, an asphalt cement; Paint No. 11, a proprietary material containing a lead pigment; Paints No. 12 and No. 13, both proprietary products of the same manufacturer; Paints No. 14 and No. 15, both proprietary products with composition unknown; and Paint No. 16, a proprietary product which was applied to both dry and wet surfaces as recommended by the manufacturer. A portion of the surface primed with Paint No. 11 was top coated with Paint No. 10, as shown.

D. TESTS RESULTS

An inspection of the paint test was held on June 29, 1954, by members of the subcommittee on the Preparation and Painting of Steel Surfaces of AREA Committee 15, together with representatives of the AAR and the Steel Structures Painting Council, for the purpose of rating the condition of the panels. Panels were rated from 0 to 10, with

10 indicating a perfect panel as far as rusting is concerned. Panels were rated for rusting only. The rating was done in accordance with the ASTM standard method of evaluating degree of resistance to rusting obtained with paints on iron or steel surfaces, ASTM designation D 610–43. Under this method of rating, a 10 is a perfect panel, while one with a slight breakdown, which generally would require no spot cleaning or spot painting, would be about 8, while a panel which required a general spot cleaning and spot priming would rate about 6. If about 25 percent of the area is covered with rust, the rating would be in the region of 4 or lower and indicates that insignificant protection of the steel is being achieved.

The inspector's ratings are shown in Table 1 with the average (or mean) ratings calculated. The average ratings are also shown on the schematic illustration of the two girders in Figs. 2 and 3, while pictures of all the panels of girder 1, except panel 8, are shown on Figs. 4 and 5. The method of surface preparation, pretreatment, priming and finish paints are shown, along with the average ratings for the flanges and webs, with comments where applicable.

Remarkably consistent ratings were obtained for almost all of the test sections. In view of the excellent agreement on ratings, a statistical analysis of the ratings was not undertaken to determine the degree of variation between ratings required for real significance. In using the ratings, it must be kept in mind that there is a slight variation, and that ratings with a difference of about 0.2 to 0.3 could possibly occur by chance; therefore, it is felt that ratings should vary by at least 0.2 to 0.3 to be deemed significant.

In connection with the evaluation of the materials and a study of the ratings, it should be pointed out that considerable difference of opinion existed in the rating of panel 8Lb; that is, the asphalt oil (Paint No. 7) by itself. Examination of this panel at regular intervals during the past three years had indicated that little or no protection was being realized by use of this asphalt oil alone after a period of one year. In rating this panel, it is difficult to arrive at a true evaluation because the appearance is deceptive. At present, the panel appears to the author to be in approximately the same condition as it was before it was coated. It appears to have a mixture of rust and asphalt residue on the surface and seems to be providing little protection. Because of this condition, the average ratings of 5.9 and 6.6 for the flange and web are believed to be far too high. One of the inspectors rated this panel as 9.0, which is an impossible rating for its condition and is actually erroneous. It should be pointed out that it was extremely difficult to rate the panels which were hand cleaned and wire brushed because of the amount of old paint that remained on the surface; in some cases the old paint was providing protection while the new material had failed. Also, the ratings were made by the inspectors without knowledge of which materials were being rated to prevent favoritism.

Another panel on which some comment is deserved is panel 8R, primed with Paint No. 2, and with Paint No. 10 top coat over one-half of the area. This panel as well as panel 9 had been damaged by a weed burner entering the bridge and burning the paint. All of the top coat had been burnt off the web, and the primer had been discolored so that it looked as though it were beginning to rust. Actually, insignificant rusting had occurred even on the portions of the test area which had been damaged by the weed burner. Panel 9 coated with the grease compound had been damaged to the point where the coating formed large globules; however, it was still providing complete protection to the steel.

TABLE 1 INSPECTOR'S RATINGS

Test Section	Inspector 1		Inspector 2		Inspector 3		Inspector 4		Inspector 5		Inspector 6		Inspector 7		Inspector 8		Inspector 9		Inspector 10		Average Ratings	
	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web	Flange	Web
Girder 1																						
1La	9.5	9.0	9.5	9.5	9.5	9.0	9.5	8.0	9.0	9.0	9.5	9.0	9.5	9.5	9.5	9.5	9.5	9.0	9.5	9.5	9.45	9.10
1Lb	9.0	8.0	8.5	8.0	8.5	8.0	8.0	7.0	7.0	7.0	7.5	8.0	7.0	8.0	7.5	7.0	8.5	8.0	8.5	8.0	8.00	7.70
1Ra	9.5	8.5	9.5	8.5	9.5	8.5	9.0	8.0	8.0	8.0	9.8	8.5	9.8	9.0	9.5	8.5	9.0	8.5	9.5	9.0	9.31	8.50
1Rb	9.5	8.0	9.0	8.0	9.5	8.0	9.0	7.0	8.0	7.0	9.5	8.0	9.5	7.0	9.5	8.0	9.5	8.0	9.5	8.0	9.25	7.70
2La	9.5	9.5	9.0	9.0	9.0	9.5	9.5	9.5	9.0	9.0	9.0	9.0	9.5	9.5	9.0	9.0	9.5	9.0	9.5	9.5	9.25	9.25
2Lb	7.5	4.5	7.5	4.5	7.0	5.0	7.0	1.0	6.0	4.0	7.0	5.0	8.0	6.0	6.5	5.0	7.5	4.5	8.0	6.0	7.20	4.85
2Ra	9.0	9.5	9.5	9.5	9.0	9.5	9.5	9.0	9.5	9.5	8.5	8.5	9.5	9.5	8.5	8.5	9.5	9.5	9.5	9.5	9.20	9.25
2Rb	8.5	6.0	8.5	6.5	8.5	7.0	8.5	7.5	7.5	7.0	8.0	7.0	8.5	7.0	8.0	7.0	9.0	6.0	8.5	7.0	8.35	6.80
3La	9.5	7.5	9.0	8.5	9.0	9.5	9.0	8.5	9.0	9.0	9.0	8.5	9.5	9.0	9.0	8.5	9.5	9.0	8.5	8.5	9.10	8.65
3Lb	7.0	6.0	7.0	6.0	6.0	6.0	7.0	6.0	6.0	6.0	7.5	6.5	7.0	6.5	7.0	6.0	8.0	7.5	7.0	7.0	6.95	6.35
3Ra	7.0	8.5	7.0	8.5	8.0	9.0	7.0	9.0	8.0	9.0	7.5	8.5	7.0	9.5	7.0	8.0	8.0	9.0	7.0	8.5	7.35	8.75
3Rb	4.0	4.0	4.0	4.0	2.0	3.0	4.0	4.0	3.0	3.0	5.0	5.0	3.0	2.0	5.0	5.0	5.0	5.0	4.0	4.0	3.90	3.90
4L	10.0	10.0	9.5	9.5	10.0	10.0	9.5	10.0	9.0	9.0	9.8	9.5	10.0	10.0	9.8	9.5	9.5	10.0	9.5	10.0	9.66	9.75
4R	10.0	10.0	9.5	10.0	10.0	10.0	10.0	10.0	9.0	9.0	9.5	9.0	10.0	10.0	9.5	9.0	9.5	10.0	10.0	10.0	9.70	9.70
5La	9.0	10.0	9.0	9.5	9.5	10.0	9.0	10.0	8.0	9.0	8.5	8.0	9.5	9.5	8.5	8.0	9.5	10.0	8.5	9.5	8.90	9.35
5Lb	9.5	9.0	9.5	9.0	9.7	9.8	9.5	9.5	9.0	9.0	8.5	9.8	9.0	9.5	8.5	9.5	9.5	9.5	9.0	9.0	9.17	9.36
5Ra	9.0	9.5	8.5	10.0	9.5	10.0	9.0	10.0	8.0	9.0	9.0	8.5	9.0	10.0	9.0	9.0	10.0	10.0	8.5	10.0	8.95	9.60
5Rb	8.0	9.5	7.5	9.5	9.0	10.0	8.5	9.5	8.0	9.0	8.5	9.5	7.5	9.5	8.5	9.5	9.0	9.5	7.5	9.0	8.20	9.45
6La	7.5	9.0	8.0	9.0	8.5	9.0	8.0	9.5	7.0	9.0	8.0	8.0	7.5	9.0	8.0	7.5	8.5	8.5	8.0	9.0	7.90	8.75
6Lb	6.0	9.0	6.5	9.0	7.0	8.5	4.0	8.0	5.0	8.0	7.0	8.5	4.0	9.0	7.0	7.0	7.0	9.0	6.5	9.0	6.00	8.50
6Ra	8.0	9.5	8.0	9.5	9.0	9.5	8.5	9.5	8.0	9.0	9.0	8.5	8.0	9.5	9.0	8.5	9.0	9.0	8.0	8.0	8.45	9.05
6Rb	7.5	9.5	7.5	9.5	8.0	9.0	8.0	9.5	7.0	8.0	8.0	8.5	7.5	9.5	8.0	8.5	8.0	9.5	7.5	9.5	7.70	9.10
7La	7.5	9.0	7.5	9.5	8.0	9.5	8.0	9.0	7.0	8.0	8.0	8.0	8.0	9.5	8.0	8.0	8.0	9.0	7.5	9.0	7.75	8.85
7Lb	4.5	9.5	6.5	10.0	7.5	9.0	6.0	9.5	4.0	8.0	7.0	9.0	6.0	9.5	7.0	9.0	6.5	9.5	6.5	10.0	6.15	9.30
7Ra	8.5	9.5	8.0	9.5	8.5	9.0	8.5	9.5	8.0	8.0	8.5	9.0	8.0	9.5	8.0	9.0	8.5	10.0	8.0	9.5	8.25	9.25
7Rb	8.5	9.0	7.5	6.5	6.0	8.5	8.5	9.5	7.0	7.0	7.5	7.0	8.0	9.0	7.5	7.0	8.5	9.5	7.5	6.5	7.65	7.95
8La	9.5	9.5	9.5	9.5	9.0	9.0	9.5	9.5	9.0	9.0	9.5	9.8	10.0	10.0	9.5	9.8	9.5	9.5	9.5	9.5	9.45	9.51
8Lb	4.0	6.5	7.0	7.5	3.0	2.0	7.0	9.0	4.0	5.0	6.0	6.5	7.0	7.0	6.0	6.5	8.0	8.5	7.0	7.5	5.90	6.60
8Ra	9.5	9.0	9.0	6.0	9.9	9.5	9.0	9.5	8.0	5.0	9.0	9.0	9.5	10.0	9.5	9.5	9.5	9.5	8.5	9.5	9.14	8.65
8Rb	9.5	9.0	8.0	6.5	9.5	9.5	9.0	9.5	8.0	5.0	9.0	9.0	9.5	10.0	9.0	9.0	9.5	9.5	8.0	9.5	8.90	8.65
9	10.0	10.0	10.0	10.0	10.0	10.0	9.5	10.0	9.5	9.5	10.0	10.0	10.0	10.0	10.0	10.0	9.5	9.5	10.0	9.5	9.85	9.85
Girder 2																						
1La	9.0	9.5	9.0	10.0	9.9	10.0	9.5	10.0	9.0	9.0	9.5	9.0	9.5	8.5	9.5	9.0	9.0	9.5	9.0	10.0	9.29	9.45
1Lb	8.5	8.0	8.0	9.0	9.0	9.5	8.0	9.0	7.0	8.0	8.0	8.5	8.5	9.0	8.0	8.5	8.5	9.0	8.0	9.0	8.12	8.75
1Ra	10.0	8.0	9.5	8.0	10.0	9.0	9.5	8.0	8.0	7.0	8.5	8.0	10.0	9.5	8.5	8.0	9.5	8.5	9.5	8.0	9.30	8.20
1Rb	9.0	9.5	9.0	9.5	9.8	10.0	9.0	9.5	7.0	6.0	8.0	8.0	9.8	10.0	8.0	8.0	9.0	9.5	9.0	9.5	8.76	8.95
2L	9.5	10.0	10.0	10.0	9.9	10.0	9.0	10.0	8.0	9.0	9.5	9.5	10.0	10.0	9.5	9.5	9.5	10.0	9.0	10.0	9.39	9.80
2R	10.0	10.0	9.5	9.5	9.9	10.0	10.0	10.0	9.0	9.0	9.8	9.8	9.5	10.0	9.8	9.8	9.5	10.0	10.0	10.0	9.70	9.81
3L	9.5	10.0	9.5	10.0	10.0	10.0	10.0	9.5	9.0	9.0	9.5	9.0	9.8	10.0	9.5	9.0	9.5	10.0	9.5	10.0	9.58	9.65
3R	10.0	10.0	9.5	10.0	10.0	10.0	10.0	10.0	9.0	9.0	9.0	9.0	9.5	10.0	9.0	9.0	9.5	10.0	9.5	10.0	9.50	9.70
4L	10.0	9.5	9.5	9.5	10.0	10.0	9.5	10.0	8.0	9.0	9.0	9.0	9.5	9.0	9.0	10.0	10.0	9.5	9.5	9.5	9.35	9.50
4R	9.0	4.0	9.0	6.0	9.8	6.0	9.0	---	8.0	5.0	8.5	7.0	9.0	7.0	8.5	7.0	9.5	4.0	9.0	4.0	8.93	5.56
9	9.5	9.0	10.0	9.0	10.0	9.8	9.5	9.5	8.0	8.0	9.5	9.5	10.0	9.8	9.5	9.5	10.0	9.0	10.0	9.0	9.60	9.21

Comparison of Chemically Cleaned and Pretreated Surfaces with Hand-Cleaned Surfaces

The main object of the test is to evaluate the chemically cleaned and pretreated surface versus the hand-cleaned surface. To do this, average ratings are tabulated in Table 2.

Table 2—Comparison of Chemical Cleaning and Pretreating with Hand Cleaning (Six Primers)

	Chemically Cleaned and Pretreated		*Hand Cleaned*	
	Flange	*Web*	*Flange*	*Web*
No. 1, with No. 10 top coat	9.45	9.10	8.90	9.35
No. 1, primer only	8.00	7.70	9.17	9.36
No. 2, with No. 10 top coat	9.31	8.50	9.14	8.65*
No. 2, primer only	9.25	7.70	8.90	8.65*
No. 4, with No. 10 top coat	9.25	9.25	7.90	8.75
No. 4, primer only	7.20	4.85	6.00	8.50
No. 5, with No. 10 top coat	9.20	9.25	8.45	9.05
No. 5, primer only	8.35	6.80	7.70	9.10
No. 3, with No. 10 top coat	9.10	8.65	7.75	8.85
No. 3, primer only	6.95	6.35	6.15	9.30
No. 6, with No. 10 top coat	7.35	8.75	8.25	9.25
No. 6, primer only	3.90	3.90	7.65	7.95
Overall average	7.84		8.45	
Primer only, average	6.75		8.20	
Primer and top coat, average	8.93		8.69	

*Burnt.

This table shows the ratings for paints on the chemically cleaned and pretreated surface versus the ratings for the same paints on the hand-cleaned surface. The average rating for the hand-cleaned surface is 8.45 and for the chemically cleaned and pretreated surface, 7.84. This difference is believed to be clearly significant and to show that the hand-cleaned surface is superior to the chemically cleaned and cold phosphate pretreated surface. In breaking down the analysis a little further, it appears that the primers on the hand-cleaned surfaces are out-performing the primers on the chemically cleaned and pretreated surfaces by far, as indicated by the respective ratings of 8.20 and 6.75. The total ratings, that is, for the primer and for the top coat, are 8.93 for the chemically cleaned and pretreated versus 8.69 for the hand cleaned. This difference is not believed to be significant since it could probably occur by chance due to variance in the ratings. Throughout this test, the primers have broken down faster than the complete paint systems, as would be expected. The criticism has been raised that the ratings of the primers by themselves are not a true picture of the ability of the paint to protect steel, since the primers are not intended to be used alone but to be top coated. This is a significant point to remember, but one should keep in mind that in testing paints this way, the performance of the primers alone is an indication of the performance of the complete paint system at a later date. In other words, by examining the performance of the primers by themselves, we get an early picture of what the performance of the complete paint system will be at a much later date. Furthermore, it is felt that the performance of the primer alone is of considerable interest due to the fact that considerable amounts of steel are either shop primed and exposed for long periods of time before field coating, or are primed in the field either in new work or in maintenance work and exposed for

long periods before painting is resumed or completed. It is widely felt that the performance of a primer by itself is a good indication of its overall ability to perform as a component of a paint system.

Comparison of All Surface Preparations

It is clearly evident that this test shows that the chemical cleaning and pretreating methods used here are inferior to hand cleaning by chipping and wire brushing. Before reaching any general conclusion, several other interesting features of the test should be considered. Panel No. 4 had the paint stripped chemically but no cold phosphate pretreatment was applied; Paint No. 1 was the primer used in this section. On hand-cleaned Panel No. 5 of the bridge, Paint No. 1 was used as the primer but the right half of the panel received a pretreatment. This is believed to be another cold phosphate pretreatment but the manufacturer claims that it contains selenium. An analysis of the results of the Paint No. 1 primer with and without Paint No. 10 is shown in Table 3.

Table 3—Comparison of All Surface Preparations, One Primer

	Average Ratings				
	Paint No. 1 Primer Only		*Paint No. 1 With No. 10 Top Coat*		*Average*
	Flange	*Web*	*Flange*	*Web*	
Chemically cleaned and pretreated	8.00	7.70	9.45	9.10	8.56
Chemically cleaned, no pretreatment	9.70	9.70	9.66	9.75	9.70
Hand cleaned only	9.17	9.36	8.90	9.35	9.20
Hand cleaned and pretreated	8.20	9.45	8.95	9.60	9.05

It is evident that the chemically cleaned surface which received no pretreatment has out-performed any of the other surfaces when primed with Paint No. 1. The hand-cleaned surface without any pretreatment is second to the chemically cleaned surface without pretreatment, but it is almost as good. The hand-cleaned and pretreated surface is almost equal to the hand-cleaned surface alone, and there is no clearly significant evidence that pretreatment was detrimental. The chemically cleaned and pretreated surface is shown clearly to be the worst of the surface cleaning methods tested here. In this connection, it is believed that much of the poor performance is due to the manufacturer's insistance that no chipping or wire brushing of the chemically stripped surface was necessary before pretreating. Examination of the rust and scale remaining on the surface indicated that only superficial attack of the cold phosphate solution had occurred and that large amounts of rust remained on the surface.

Comparison of Primers and Complete Paint Systems

In evaluating the performance of the primers on girder 1, the analysis is indicated in Table 4. It can be seen from the overall average values that Paint No. 1 is rated slightly above Paint No. 2, but it is not believed that the difference in rating is significant. In view of the fact that the Paint No. 2 panel on the hand-cleaned portion of the bridge was damaged by flame from the weed burner, one might conclude that the paints are equally effective. Paint No. 5 is next in the list of overall ratings, followed at a distance by Paint No. 3 and Paint No. 4; these paints do not show any significant difference in the ratings. Paint No. 6 had the poorest rating of the paints on test and the difference is clearly significant. It should be pointed out here that the poor performance of Paint No. 3, the state highway department red lead, is believed due to the faulty material which was supplied, and which at the time of application was noted as being of a spraying viscosity not suitable for brushing; as a result, it was applied at a film thickness one-half of what it should have been. Based on the ratings

of performance of the primers alone, it appears that Paint No. 1 and Paint No. 2 are again equal and superior, respectively, to the others. No. 5 is poorer than either of these two and superior to any of the other primers. No. 3 is, in turn, inferior to No. 5 and superior to No. 4 and No. 6. No. 4 is inferior to No. 3 and superior to No. 6. No. 6 by itself performed very poorly in this test.

TABLE 4—COMPARISON OF PRIMERS AND COMPLETE PAINT SYSTEMS

	Primers		*Average Ratings*					
			No. 1	*No. 2*	*No. 3*	*No. 5*	*No. 4*	*No. 6*
Chemically Cleaned and Pretreated	With Top coat	Fl.	9.45	9.31	9.10	9.20	9.25	7.35
		Web	9.10	8.50	8.65	9.25	9.25	8.75
	Primer Only	Fl.	8.00	9.25	6.95	8.35	7.20	3.90
		Web	7.70	7.70	6.35	6.80	4.85	3.90
Hand Cleaned	With Top coat	Fl.	8.90	9.14	7.75	8.45	7.90	8.25
		Web	9.35	8.65	8.85	9.05	8.75	9.25
	Primer Only	Fl.	9.17	8.90	6.15	7.70	6.00	7.65
		Web	9.36	8.65	9.30	9.10	8.50	7.95
Overall average			8.88	8.76	7.89	8.49	7.71	7.13
Average, primer only			8.56	8.63	7.19	7.99	6.64	5.85
Average complete system			9.20	8.90	8.59	8.99	8.79	8.40

The differences in the ratings for the complete paint systems are not great, varying from 9.20 for the highest to 8.40 for the lowest. This is due to the excellent condition of the complete systems, which is to be expected, since the paints were exposed for only three years. Based upon the ratings of the complete paint systems so far, Paint No. 1 is out-performing all of the other paints. No. 5 and No. 2 are performing very well and close to No. 1; No. 3 and No. 4 are about on a par and are superior to No. 6.

Protective Coatings and Other Paints

Paint No. 7, asphalt oil, alone is very poor, but when top coated with asphalt bridge cement is excellent; however, the bridge cement by itself is doing just as well on the second girder. The grease coating, Paint No. 9, is completely protecting the steel, but is heavily coated with dirt and cinders.

It is believed premature to draw conclusions regarding the paints on test on girder 2. With the exception of the bridge cement on panel 9, all of the paints have been on test less than two years. Furthermore, the area of old paint still adhering to this girder is greater than on the girder in the main portion of the test. Average ratings for this portion of the test are shown in Fig. 3. The bridge cement appears in perfect condition, but this type of coating as well as the other thick coatings usually fail by undercutting by rusting which is not generally noticeable until the coating fails by stripping off in large patches. Paint No. 16, which was applied to a wet surface, failed by adhesion and undercutting of rust on large patches of the surface (see Fig. 6); this paint is also extremely brittle. Paint No. 11 is providing protection but is chalking badly and eroding fast; in addition, the top coat of Paint No. 10 has poor adhesion to the Paint No. 11 under coat and is flaking off. This Paint No. 11 itself has very poor adhesion to the steel and is quite brittle. The remainder of the materials in this portion of the test appear to be providing virtually complete protection.

E. CONCLUSIONS

Based on the average ratings for the various test sections the following conclusions appear to be valid for this test:

1. The surfaces prepared by chemical cleaning and cold phosphate pretreating are inferior to those prepared by hand chipping and hand wire brushing.
2. Chemical cleaning by use of a paint stripper of the flush-off type is a satisfactory method of surface preparation, provided that cleaning of the surface to remove rust and scale is a subsequent operation and the cold phosphate pretreatment is omitted.
3. The proprietary pretreatment containing seleium is either of no effect or slightly detrimental to the performance of the paint on hand-cleaned surfaces.
4. Complete protection of hand-cleaned steel for three years has been achieved through the use of asphalt oil followed by one coat of asphalt bridge cement after drying for several months, and by one thick coat of grease compound, and by bridge cement alone. One coat of asphalt oil by itself provides little protection after a period of about one year.
5. At the present time, the six primers on test rank in the following order of effectiveness: First, Paint No. 1 (SSPC Paint No. 2) and Paint No. 2 (TT–P–86a, Type I); second, Paint No. 5; third, Paint No. 3 and Paint No. 4; fourth, Paint No. 6.
6. The state highway department red lead paint submitted was of inferior quality and had a Zahn No. 3 viscosity of about one-third to one-half of that necessary for a satisfactory brushing.
7. None of the paints or other rust-preventive materials tested was effective in painting over very heavy rust scale; all rust scale which was painted failed by loosening of the rust scale and exposure of fresh metal in a few months.
8. Based on the high cost of the chemical paint stripping, hand cleaning by chipping and wire brushing is the most economical of the surface preparation methods tested. No advantage occurred from the removal of sound, adherent paint other than better appearance. No advantage occurred from either of the pretreatments tested.

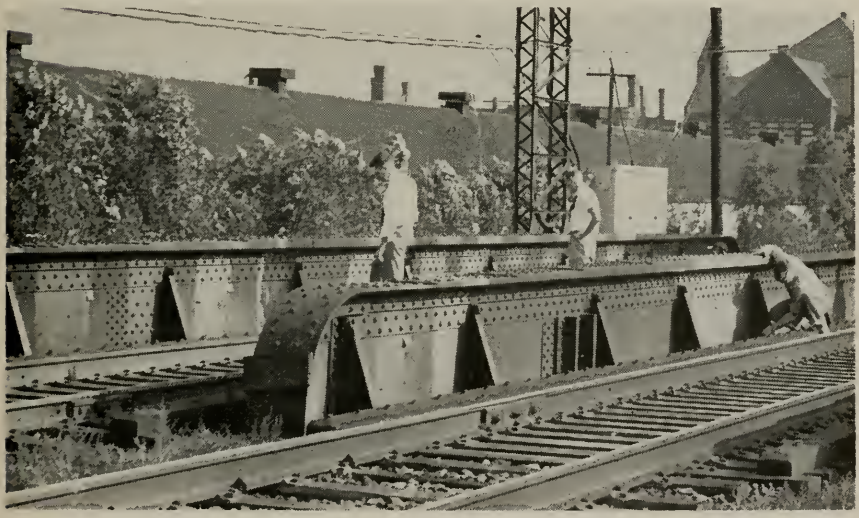


Fig. 1—General view of girders used for cleaning and painting tests.

Comments (Exposed three years)	Average Ratings Web	Average Ratings Flange	Finish	Primer	Surface Treatment	Method of Cleaning
	9.10	9.45	Paint No.10	Paint No 1	Cold phosphate solution sprayed on surface and allowed to dry.	Paint removed chemically with flush-off paint remover and steam (hot water under pressure); surface about 25% rust, 75% millscale.
	7.70	8.00	None			
Cleaned and chemically treated steel exposed 19 days before priming	8.50	9.31	Paint No.10	Paint No 2		
	7.70	9.25	None			
	9.25	9.25	Paint No.10	Paint No.4		
	4.85	7.20	None			
	9.25	9.20	Paint No.10	Paint No 5		
	6.80	8.35	None			
Primer too thin; applied at double usual coverage.	8.65	9.10	Paint No.10	Paint No.3		
	6.35	6.95	None			
	8.75	7.35	Paint No.10	Paint No.6		
	3.90	3.90	None			
Cleaned steel exposed before priming	9.75	9.66	Paint No.10	Paint No.1	None	Paint partially removed chemically, cold water.
	9.70	9.70	None			
	9.35	8.90	Paint No.10	Paint No.1	None	Hand cleaned in usual railroad manner by chipping and wirebrushing; surface about 25% rust, 75% old paint.
	9.36	9.17	None			
* Rust Remover	9.60	8.95	Paint No.10	Paint No.1	*	
	9.45	8.20	None			
	8.75	7.90	Paint No.10	Paint No.4	None	
	8.50	6.00	None			
	9.05	8.45	Paint No.10	Paint No.5		
	9.10	7.70	None			
Primer too thin; applied at double usual coverage.	8.85	7.75	Paint No.10	Paint No.3		
	9.30	6.15	None			
	9.25	8.25	Paint No.10	Paint No.6		
	7.95	7.65	None			
	9.51	9.45	Paint No 8	Paint No.7		
	6.60	5.90	None			
Weed burner burnt paint	8.65	9.14	Paint No.10	Paint No.2		
	8.65	8.90	None			
Weed burner melted coating and caused runs	9.85	9.85	None	Paint No.9		
	6/29/54	6/29/54	7/2/51, except for 1Rg and 4L on 7/6/51, and 8Lg on 9/7/51, and 9 on 6/25/51.	6/13/51, except for 1R, 4, and 8L on 7/2/51.	6/13/51	6/13/51, except 4 on 4/18/51.

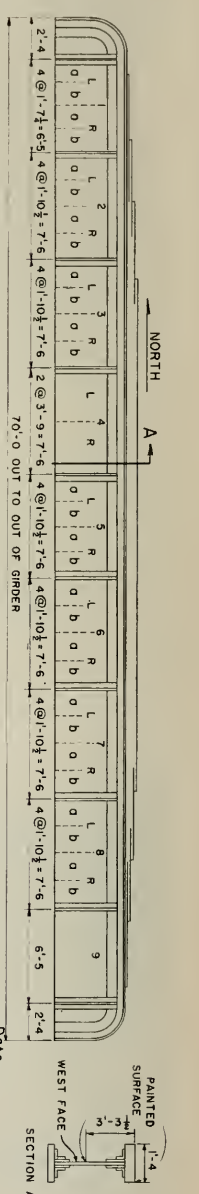


Figure 2 PAINTING SCHEME AND AVERAGE RATINGS FOR TEST GIRDER 1

Comments	Average Ratings Web	Average Ratings Flange	Finish	Primer	Surface Treatment	Method of Cleaning	Date
Top coat disappearing Chalking badly	945	929	Paint No.10	Paint No 11 8/7/52	None	Hand cleaned in usual railroad manner by chipping and wirebrushing; surface about 25% rust, and 75% old paint.	8/7/52
	875	812	None				
Top coat disappearing Chalking badly	820	930	Paint No. 10	Paint No 11 8/7/52			
	895	876	None				
	980	939	Paint No.12 total $\frac{1}{16}$" thick 9/19/52	Paint No 12 9/17/52			
	981	970	Paint No 13 total $\frac{1}{16}$" thick 9/22/52	Paint No 13 9/19/52			
	965	958	None	Paint No 14 right half painted before storm, left half after 9/22/52			
	970	950	None	Paint No 15 $\frac{1}{16}$" thick 11/5/52			
	950	935	Paint No.16 11/6/52	Paint No 16 11/5/52			
One large area no adhesion; rust under paint	556	893	Paint No.16 wet surface 11/6/52	Paint No 16 wet surface 11/5/52			
	921	960	None	Paint No 8 9/7/51	None	Hand cleaned, etc.	8/7/52
	6/29/54	6/29/54	as noted, except for ILa and IRa on 8/7/52	as noted			

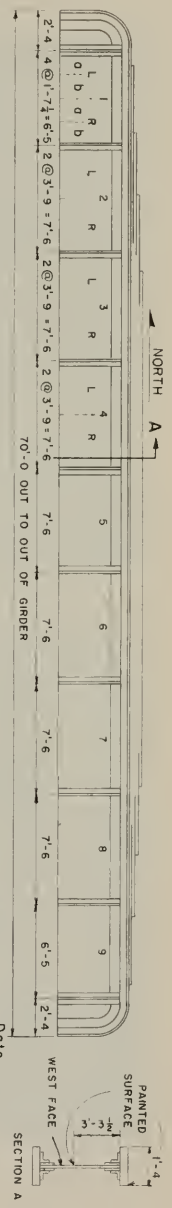


Figure 3 PAINTING SCHEME AND AVERAGE RATINGS FOR SECONDARY TEST GIRDER 2.

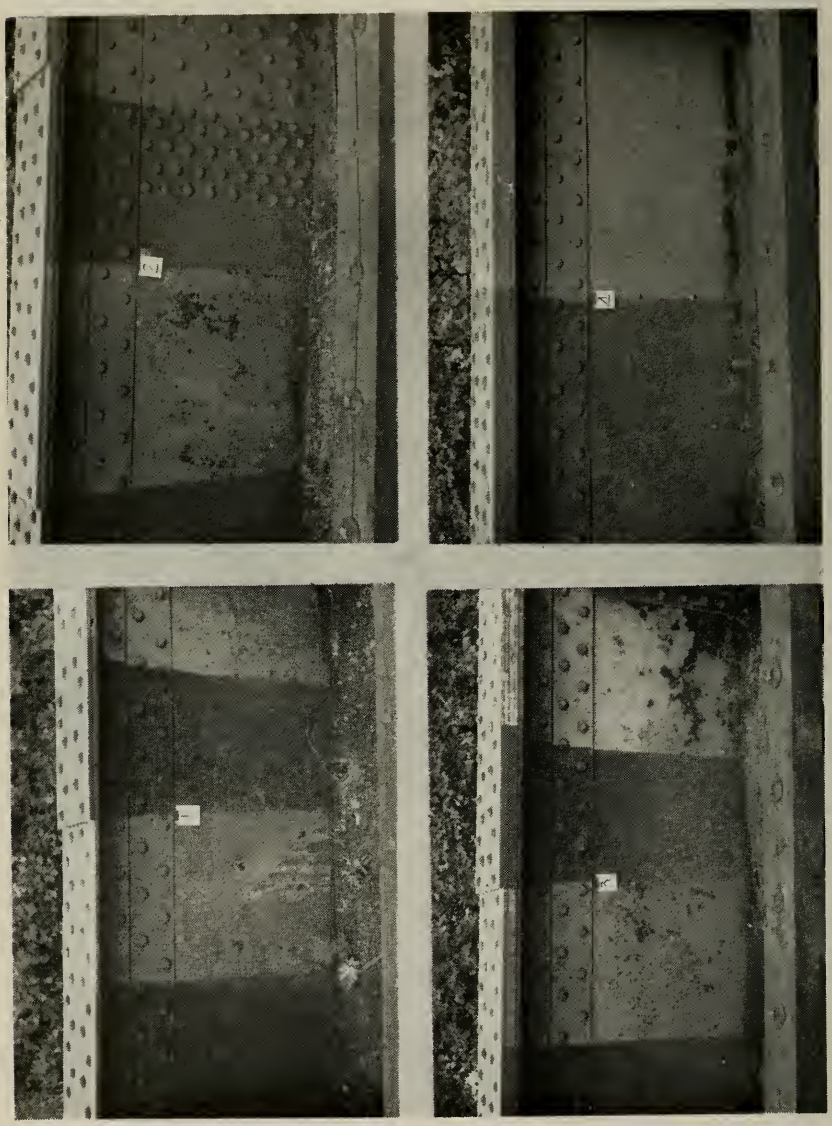


Fig. 4—General views of test panels 1 to 4 on girder 1.

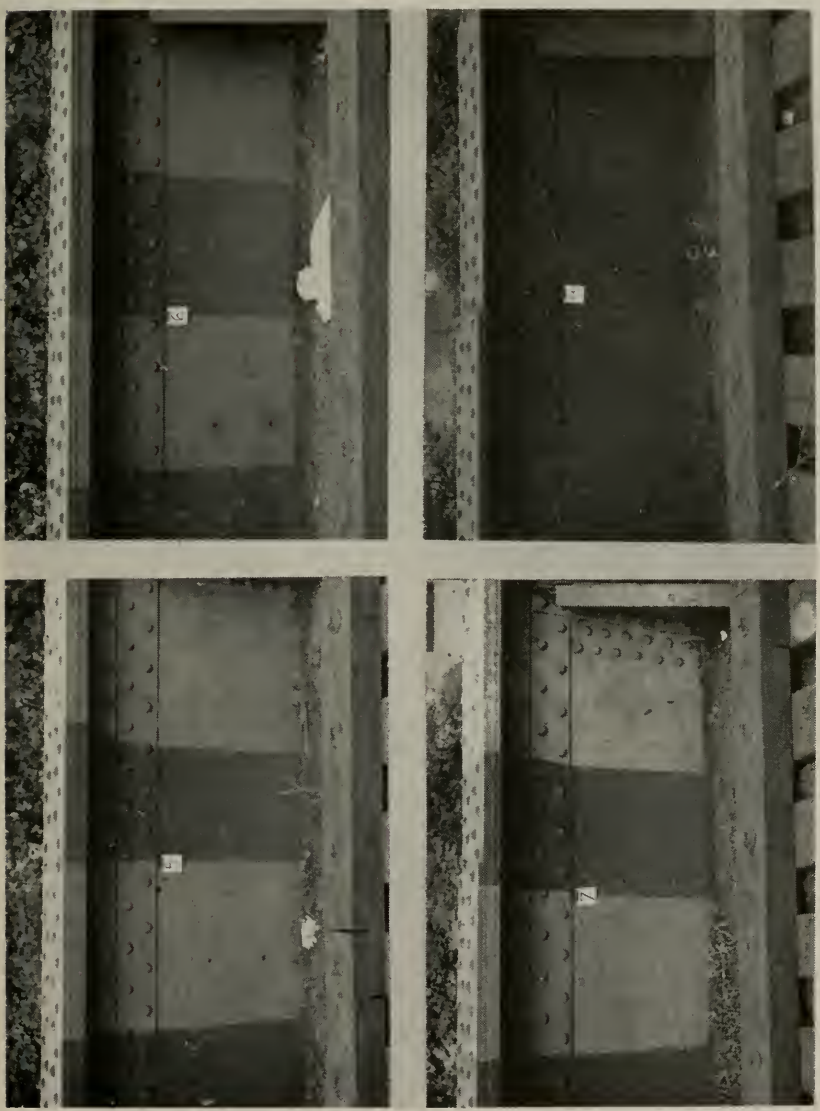


Fig. 5—General views of test panels 5, 6, 7, and 9 on girder 1.

Fig. 6—General view of test panel 4 on girder 2.

Paint No.	*Identification and Description*
1	Proprietary red lead iron oxide primer. Equivalent to Steel Structures Painting Council Paint No. 2
2	Railroad company's red lead paint complying with federal specification TT–P–86a Type I
3	State highway department red lead paint similar to Paint No. 2
4	Proprietary product
5	Proprietary paint for rusty surfaces
6	Proprietary product. Extended red lead. Semi-quick drying
7	Asphalt oil
8	Asphalt cement
9	Proprietary grease rustproofing compound
10	Railroad company's finish coat
11	Proprietary product (lead pigment)
12	Proprietary product
13	Proprietary product
14	Proprietary product
15	Proprietary product
16	Proprietary product

Fig. 7.

Advance Report of Committee 30—Impact and Bridge Stresses

E. S. Birkenwald, *Chairman*

Tests of Steel Girder Spans on the Milwaukee Railroad

A. DIGEST

This report contains a description and analysis of the test data obtained on 10 single-track plate-girder spans, with lengths varying from 40 to 140 ft, and one 35-ft beam span, all on the Chicago, Milwaukee, St. Paul & Pacific Railroad. The 10 girder spans, in 6 test bridges, are on the main line of the railroad between Chicago and Omaha, Neb., where both high-speed diesel and steam locomotives were operating each day at the time of the test. Six of the spans are of open timber floor construction, while the remaining 4 spans have a ballasted track with a solid timber floor. The tests were made under regular scheduled trains at speeds varying from 2 mph up to the maximum operating speed of 100 mph for the diesels and 90 mph for some of the steam locomotives. Stresses were measured for 329 diesel locomotives and 416 steam locomotives, or a total of 745 locomotive test runs on the 6 bridges.

The stresses were measured by means of electromagnetic strain gages or SR–4 wire strain gages with oscillograph recordings, and readings were taken in various parts of each structure, such as:

Bottom flanges at the center of the span.
Top flanges at the center of the span.
Edges of both the top and bottom flanges at the center of the span.
Top flange cover plates near the end of one of the cover plates.
Web plates at the end of the span.
Web plates at the quarter point of the span.
Lateral and cross frame bracing.

The tests were conducted as a part of a research program to determine the static and dynamic effects in plate-girder bridges; the final conclusions will be based on the results obtained in 36 plate-girder spans varying in length from 40 to 140 ft.

The data secured during these tests were analyzed for the purpose of determining the static and total impact effects, as well as the individual effects which contribute to the total impacts. A brief summary of the analysis of the data follows:

1. There was considerable variation between the static stresses recorded in the flanges at the centers of the girders and those calculated by the usual method, as shown in Tables 2 and 3. The ratios of the recorded stresses to the calculated stresses varied from 0.72 in the 40-ft deck span to 1.04 in the 110-ft 2-in through plate-girder span.

2. The effect of the stringers and lateral bracing in reducing the static stresses in the flanges is indicated by the average stress factors for the through girder span. The average stress factors for the 85-ft, 107-ft and 140-ft through girder spans varied from 0.74 to 0.90, but the stress factors for the 94-ft 10-in deck span were 0.98 for the diesels and 0.88 for the steam locomotives, as shown in Col. 9 of Table 3.

3. A comparison of the recorded and calculated static stresses in the web plates of the girders close to the ends of the spans is shown in Table 4. It can be seen that this ratio varied from 0.74 for the steam locomotives on one 40-ft deck plate-girder span to 0.99 for the diesel locomotives on the 94-ft 10-in deck plate-girder span; however, a stress factor of 0.58 for diesel locomotives on a 40-ft span was found.

4. A comparison of the recorded and calculated static stresses in the web plates of the girders close to the quarter points of the span is shown in Table 5 for the 107-ft, 110-ft and the 140-ft spans; it can be seen that the stress factors varied from 0.79 to 0.87.

5. A comparison of the recorded and calculated static live-load stresses in the lower flanges of the stringers and center floorbeams of 3 of the through plate-girder spans is shown in Table 5. Considerable variation was found in the stress factors, and it can be seen that average values from 0.73 in the stringers of the 140-ft span to 1.03 in the stringers of the 107-ft span were found. It can also be seen that the average recorded static stresses at the center line of stringers were slightly greater than the calculated for the steam locomotives.

6. A comparison of the stresses recorded in the top and bottom flanges of 4 of the longer girder spans is shown in Table 6. The effect of the composite action between the stringers and lower flanges is evident from the data shown in this table. The average stress in the top flanges of the through plate girders varied from 4 percent greater than the stress in the bottom flanges of the 107-ft span to 23 percent greater in the 85-ft span. However, the stress in the top flanges of the 94-ft 10-in deck plate-girder span averaged about 4 percent less than the stress in the bottom flanges.

7. An increase or decrease in the average mean stresses of both girders over the slow-speed run has been termed "speed effect". This effect was found throughout these tests, as is shown in the upper left diagrams of Figs. 17 to 56, incl. A large number of negative speed effects were recorded, which were, undoubtedly, the result of the vertical acceleration of the unsprung weight of the locomotives reducing the axle loads. About 75 percent of the readings under both diesel and steam locomotives were within a range of plus or minus 10 percent of the recorded static stresses. It appears that the magnitude of the speed effects caused by the diesel locomotives and those caused by the steam locomotives, as a percentage of the recorded static stresses, is about equal.

8. The simultaneous stress measurements usually indicated an increase in stress in the girder under one rail with a corresponding decrease under the other rail. This change in stress is termed "roll effect", and this effect on the 10 bridges is shown in the lower left diagrams of Figs. 17 to 56, incl. The roll effects were generally within the AREA design specification allowance, with only about 6 percent of the total readings exceeding this allowance. The magnitude of the rolling effects does not appear to bear any relation to the speed of the locomotive.

9. The oscillograms showed that vibrations were induced in the test spans by the diesel locomotives, even though their wheels had no unbalanced counterweights. This impact has been termed "track effect," and is presumably caused by irregularities in the track surface, flat spots, or out-of-round wheels. The track effects under the diesel locomotives are shown on the right diagrams of Figs. 17 to 31, incl., the recorded track-effect stresses resulting from the vibrations being shown by the upper diagrams and the track-effect percentages by the lower diagrams.

The track effect generally increased with an increase in speed without evidence of any critical or synchronous speed.

10. The combined track and hammer-blow stresses recorded under the steam locomotives are shown on the upper right diagrams of Figs. 32 to 56, incl., while the track and hammer-blow percentages are shown on the lower diagrams. The track and hammer-blow stresses are similar to those shown on the typical oscillogram, Fig. 16.

The track and hammer-blow effects in the longer spans usually increased with an increase in speed up to a certain critical or synchronous speed and then decreased some-

what with a further increase in speed. For the shorter spans synchronous speeds were not attained.

11. The total impact effects in the flanges near the centers of the spans, produced by the diesel and steam locomotives, are shown on the diagrams of Figs. 57 to 67, incl. A comparison of the values determined by the current AREA design specification with the maximum recorded values, and with the average of the 6 highest recorded values, is shown in Table A. It is interesting to note that many of the maximum recorded total impact percentages exceeded the AREA design values and that in many instances the values for the diesels exceeded those for steam locomotives.

12. The total impact effects in the girder webs at the ends of the spans and in the webs at the quarter points of the 107-ft and 140-ft spans, produced by the diesel and steam locomotives, are shown on the diagrams of Figs. 68 to 79, incl. A comparison of the values determined by the current AREA design specification with the maximum recorded values and with the average of the 6 highest recorded values is shown in Tables B and C. Impact percentages higher than design values, particularly under diesels, were found in the webs as well as the flanges.

13. The recorded maximum stresses in the flanges near the centers of the spans, produced by the diesel and steam locomotives, are shown by the diagrams on Figs. 80 to 90, incl. A comparison of the calculated values, using AREA design impact, with the maximum recorded values and with the average of the 6 highest recorded values, is shown in Table A.

14. The recorded maximum stresses in the girder webs at the ends of the spans and in the webs at the quarter points of the 107-ft and 140-ft spans, produced by the diesel and steam locomotives, are shown on Figs. 91 to 102, incl. A comparison of the calculated values, using AREA design impact, with the maximum recorded values and with the average of the 6 highest recorded values, is shown in Tables B and C.

15. The maximum direct stresses recorded in the lateral bracing and cross frames of 2 deck spans and in the lateral bracing of 4 through spans are shown on the diagrams of Tables 12 and 13.

16. A comparison of the recorded maximum direct stresses and the calculated stresses in the top and bottom lateral bracing of 6 spans is shown on Table 14. The recorded maximum stresses in the top laterals were less than the calculated stresses; however, 2 values resulted in corresponding lateral loads in excess of the AREA nosing load of 20 kips. In the bottom laterals many maximum recorded stresses exceeded the calculated values, and the corresponding lateral loads for these stresses varied from 20.2 to 37.8 kips.

17. The recorded simultaneous stresses across the top flanges of 2 spans and across both the top and bottom flanges of 2 other spans are shown in Tables 7, 8 and 9. The difference between the stresses on the edges of the same girder flange was small, indicating very little bending of the flange about a vertical axis. A few values on the 107-ft span indicate high bending, but the average on all the flanges was about 6 percent.

18. The distribution of stress between the cover plates and flange angles for 1 span is shown by the lower diagram of Table 10. It is evident that the flange angles were not carrying as much of the load as theory would predict.

The transverse bending in the cover plates and flange angle fillets, resulting from the ties bearing on the inside edge of the flange, is shown in Table 10. The transverse stress in the cover plate indicates considerable bending, but the stresses on the fillets of the flange angles were quite low.

19. The development of the stresses in the cover plates by the flange rivets is shown by the two diagrams on Table 11. It can be seen that for these low stresses the cover plates are carrying their full stress at a section about 9 in from the end of the plate.

20. Since the readings were secured under practically all the trains passing over the bridges during the test period, valuable data were secured on the frequency of occurrence of the maximum stresses. A summary of the maximum stresses recorded in 1 girder of each test span under all the test locomotives and data on the frequency of occurrence of the maximum stresses are shown on Figs. 103 to 113, incl. The data for all the test spans indicate that only a small percentage of the trains passing over the bridges produced stresses in the higher range. A comparison of the maximum stresses recorded under diesel and steam locomotives is shown by these diagrams, and it can be seen that the stresses under the diesel locomotive were about 60 percent of those recorded under the steam locomotives.

21. A study of the maximum recorded stresses in the web plates of 3 girder spans using single SR–4 gages at 45 deg and SR–4 strain rosette gages is shown on Table 15. The study indicates that stresses recorded by single SR–4 gages at 45 deg on the web varied from 6.8 to 23.5 percent higher than the maximum principal stresses found using SR–4 strain rosette gages at the same location on the webs.

(Text continued on page 24)

TABLE A. GIRDER FLANGES AT CENTER OF SPAN

Span	Locomotive Class	TOTAL IMPACTS - PERCENT			MAXIMUM STRESS - KSI		
		AREA Design	Maximum Recorded	Average Recorded (6 highest)	AREA Design	Maximum Recorded	Average Recorded (6 highest)
35'-0"	2-Axle Diesel	57.8	13.2	7.07	5.18	3.27	3.15
	3-Axle Diesel	57.8	12.7	5.01	5.54	3.64	3.53
	Class L2b	77.7	34.7	23.4	8.46	5.91	5.29
	Class S3	77.7	29.2	15.7	9.06	7.34	6.43
40'-0" Eastbound	2-Axle Diesel	50.5	64.8	48.2	6.14	4.51	4.08
	3-Axle Diesel	50.5	37.2	17.8	5.84	4.61	4.13
	Class S2	70.3	77.1	62.5	11.04	9.70	8.34
	Class S3	70.3	47.7	37.5*	9.93	6.91	6.23*
40'-0" Westbound	2-Axle Diesel	50.5	51.9	38.2	6.14	4.32	3.94
	3-Axle Diesel	50.5	57.6	45.3	5.84	4.53	4.25
	Class S2	70.3	43.3	26.3	11.04	7.17	6.25
	Class S3	70.3	42.5	25.2	9.93	6.43	5.58
46'-8 3/4"	Class A	68.3	48.3	37.8	8.86	6.61	6.47
	Class L2b	68.3	23.0	13.4	10.83	7.49	6.92
	Class S2	68.3	41.2	32.3	13.49	9.56	9.09
	Class S3	68.3	34.6	29.9	12.50	7.84	7.60
55'-0" Eastbound	2-Axle Diesel	47.6	46.1	38.6	6.36	4.07	3.90
	3-Axle Diesel	47.6	23.2	13.6	6.32	4.25	4.01
	Class S2	67.2	38.3	33.6	11.97	8.00	7.74
	Class S3	67.2	41.9	21.5	10.90	7.43	6.55
55'-0" Westbound	2-Axle Diesel	47.6	35.1	23.0	6.36	4.44	3.99
	3-Axle Diesel	47.6	45.9	32.3	6.32	4.58	4.39
	Class S2	67.2	40.1	24.3	11.97	8.00	7.37
	Class S3	67.2	39.5	20.6*	10.90	7.26	6.17
85'-0"	2-Axle Diesel	33.3	16.3	10.0	5.25	3.41	3.31
	3-Axle Diesel	33.3	27.4	23.4	5.12	3.77	3.47
	Class L2b	52.1	37.3	33.8	7.86	5.29	5.12
	Class S3	52.1	22.6	15.7	10.29	6.24	6.19
94'-10"	2-Axle Diesel	38.1	22.8	20.5	5.25	4.12	4.05
	3-Axle Diesel	38.1	16.5	13.8	5.88	4.63	4.60
	Class S2	55.4	18.9	16.3	10.77	7.17	7.08
	Class S3	55.4	23.5	12.4	10.11	7.15	6.47
107'-0"	2-Axle Diesel	29.7	23.7	19.3	4.95	4.56	4.25
	3-Axle Diesel	29.7	23.8	20.1	4.46	3.94	3.72
	Class S2	43.4	19.8	13.2	9.84	7.27	6.53
	Class S3	43.4	20.9	15.8	9.16	6.90	6.34
110'-2"**	Class A	41.7	26.0	22.8	6.98	6.78	6.42
	Class L2b	41.7	46.4	36.1	6.06	6.62	6.18
	Class S2	41.7	25.0	20.9	9.37	8.17	8.00
	Class S3	41.7	26.9	23.5	8.76	7.90	7.65
140'-0"	2-Axle Diesel	26.8	29.3	23.2	4.85	4.26	4.04
	Class L2b	33.8	44.9	36.5	5.90	4.84	4.58
	Class S2	33.8	26.0	22.5	8.79	6.72	6.42
	Class S3	33.8	15.5	10.1	8.17	5.99	5.79

* Based on Four Values. ** Values were recorded in top flenges for this span.

TABLE B. GIRDER WEBS AT END OF SPAN

Span	Locomotive Class	TOTAL IMPACTS - PERCENT			MAXIMUM STRESS - KSI		
		AREA Design	Maximum Recorded	Average Recorded (6 highest)	AREA Design	Maximum Recorded	Average Recorded (6 highest)
40'-0" Eastbound	2-Axle Diesel	50.5	67.0	34.1	5.34	3.99	3.26
	3-Axle Diesel	50.5	37.2	22.2	5.16	3.76	3.26
	Class S2	70.3	60.2	47.4	8.92	6.17	5.73
	Class S3	70.3	11.4	7.0*	8.12	4.90	4.56*
40'-0" Westbound	2-Axle Diesel	50.5	50.7	41.2	5.34	3.18	2.73
	3-Axle Diesel	50.5	64.3	32.9	5.16	2.99	2.68
	Class S2	70.3	28.6	22.5	8.92	4.99	4.54
	Class S3	70.3	38.2	24.8	8.12	4.88	4.19
46'-8 3/4"	Class A	68.3	72.9	63.6	6.13	5.68	5.34
	Class L2b	68.3	47.5	20.2	6.95	6.05	5.01
	Class S2	68.3	49.9	45.7	8.72	7.60	7.07
	Class S3	68.3	54.4	39.0	8.00	6.53	5.79
55'-0" Eastbound	2-Axle Diesel	47.6	44.8	37.9	5.22	4.02	3.62
	3-Axle Diesel	47.6	44.6	18.6	5.29	4.70	3.81
	Class S2	67.2	47.1	39.1	8.69	6.72	6.19
	Class S3	67.2	26.0	11.2*	7.98	5.97	4.81*
55'-0" Westbound	2-Axle Diesel	47.6	38.4	32.0	5.22	3.79	3.56
	3-Axle Diesel	47.6	17.3	15.1	5.29	3.73	3.53
	Class S2	67.2	30.1	27.1	8.69	6.09	5.91
	Class S3	67.2	28.5	19.8*	7.98	5.51	4.71
85'-0"	2-Axle Diesel	33.3	27.6	14.3	4.18	2.91	2.71
	3-Axle Diesel	33.3	30.1	17.9	4.02	3.00	2.85
	Class L2b	52.1	32.0	27.0	6.16	3.88	3.67
	Class S3	52.1	14.8	13.7	7.41	4.50	4.42
94'-10"	2-Axle Diesel	38.1	39.6	28.9	3.14	2.34	2.19
	3-Axle Diesel	38.1	50.0	33.3	3.38	2.76	2.55
	Class S2	55.4	24.9	19.8	6.01	4.01	3.89
	Class S3	55.4	19.0	9.8	5.50	3.69	3.31
107'-0"	2-Axle Diesel	29.7	38.9	16.9	3.49	3.20	2.75
	3-Axle Diesel	29.7	9.1	7.9	3.01	2.40	2.25
	Class S2	43.4	18.9	12.9	6.57	4.40	4.23
	Class S3	43.4	74.0	37.4	6.02	4.00	3.25
110'-2"	Class A	41.7	47.1	37.5	4.68	4.81	4.23
	Class L2b	41.7	40.7	34.7	4.44	3.87	3.81
	Class S2	41.7	52.7	43.9	6.55	6.02	5.48
	Class S3	41.7	54.6	47.1	6.03	5.34	4.83
140'-0"	2-Axle Diesel	26.8	70.0	34.7	2.79	2.80	2.27
	Class L2b	33.8	33.3	19.5	3.49	2.60	2.28
	Class S2	33.8	71.9	26.1	4.78	4.40	3.50
	Class S3	33.8	40.1	16.6	4.46	3.60	2.98

* Based on Four Values.

TABLE C. GIRDER WEBS AT QUARTER POINT OF SPAN

Span	Locomotive Class	TOTAL IMPACTS - PERCENT AREA Design	Maximum Recorded	Average Recorded (6 highest)	MAXIMUM STRESS - KSI AREA Design	Maximum Recorded	Average Recorded (6 highest)
	2-Axle Diesel	29.7	65.3	52.8	1.95	1.90	1.68
	3-Axle Diesel	29.7	7.7	---	1.82	1.40	1.30
107'-0"	Class S2	43.4	42.1	26.0	3.52	2.70	2.43
	Class S3	43.4	31.7	22.8	3.30	2.70	2.52
	2-Axle Diesel	26.3	90.0	70.1	1.61	3.40	2.15
	Class L2b	33.8	40.0	27.7	2.14	1.80	1.62
140'-0"	Class S2	33.8	32.0	19.5	2.86	2.80	2.30
	Class S3	33.8	75.0	42.1	2.69	3.10	2.50

Fig. 1—Bridge No. Z-204 near Genoa, Ill. View of 40-ft and 55-ft deck girder spans.

Fig. 2—Bridge No. Z–814 near Cedar Rapids, Ia. View of 94-ft 10-in deck girder span.

Fig. 3—Bridge No. Z–882 in Elberon, Ia. View of 46-ft 8¾-in deck girder span and 110-ft through girder span.

Fig. 4—Bridge No. Z–1500 near Persia, Ia. View of 35-ft beam span and 85-ft through girder span.

Fig. 5—Bridge No. Z–1566 in Weston, Ia. View of 107-ft through girder span.

Fig. 6—Bridge No. Z–1510 in Yorkshire, Ia. View of 140-ft through girder span.

B. FOREWORD

The assignments of Committee 30 include one on stresses and impacts in the flanges, web plates and lateral bracing of steel girder spans with open decks and with ballasted decks. To secure data for these assignments, the AAR research staff arranged to conduct tests of girder spans of various lengths and types on several railroads where both diesel and steam locomotives were operating at high speeds. In selecting these girder spans, an effort was made to choose 4 girder spans of the same length, including 1 open-track span of light design, 1 open-track span of heavy design, 1 ballasted-track span of light design and 1 ballasted-track span of heavy design. Since these requirements could not be met and still have the bridges in high-speed territory, it was necessary to select bridges of various span lengths, capacities and types of decks.

A total of 36 different spans were selected and tested on various railroads and reports covering the results obtained on 21 spans, including the 10 spans in this report, have been published. The 10 girder spans in 6 bridges on the Milwaukee Road analyzed in this report are on the main line between Chicago and Omaha, Neb., where both high-speed diesel and steam locomotives were operating each day at the time of the tests. The bridges are all in single-track territory, except the bridge near Genoa, Ill., containing the 40-ft and 55-ft spans, which is in double-track territory but was constructed of single-track spans. The 10 girder spans tested varied in length from 40 to 140 ft, with 6 of the spans being of the deck type and 4 of the through type. Six of the spans had open timber decks and the remaining 4 spans had ballasted decks with timber floors. Additional data were secured on a 35-ft approach beam span as well as data on the stringers and floorbeams of some of the through-girder spans.

The tests on the 46-ft 8¾-in and 110-ft spans in the bridge near Alberon, Ia., were conducted in 1945, and the remaining bridges were tested in 1950 and 1951. The tests were conducted under regular scheduled trains, and the amount of water and fuel in the tender at the time each train crossed the bridge was estimated by keeping a record of the water and fuel at the nearest fueling station. The recorded stresses were then corrected for the variation in tender weights, which correction, of course, applied only to the longer spans. For example, on the 140-ft span the recorded stresses under the 4–8–4 type (Class S2) locomotive were increased 0.66 ksi when the tender was half full at the time the train crossed over the bridge. Arrangements were made with the operating department of the railroad to have the trains cross the test bridge at various speeds ranging from 5 mph, which is considered the same as static loading, to the maximum operating speeds of the locomotives. Telephone service was provided between the bridge and the dispatcher by placing a telephone in the test building.

The general procedure in conducting the tests was to erect a 6 by 8-ft sectional test building at one end of the bridge, in which were placed the instruments, special care being taken to set the recording oscillographs, amplifiers and power units on sponge-rubber pads to eliminate any damage to the equipment from vibration. The gages were individually calibrated and then erected on the various elements of the spans to be tested. Recordings were then secured on most of the trains crossing over the bridge for about two weeks, depending upon the number of trains per day. The recordings were taken with the track in normal operating condition, and no effort was made to determine the effect of battered rail joints.

The bridge impact tests analyzed in this report were conducted for AREA Committee 30—Impact and Bridge Stresses, and were carried out under the general direction of G. M. Magee, director of engineering research, Engineering Division, AAR. The funds necessary for the tests and analysis of the data were provided by the AAR.

The conduct of the tests, analysis of data, and preparation of the report were under the direction of E. J. Ruble, research engineer structures, Engineering Division, AAR, assisted in the office by A. A. Sirel, formerly assistant research engineer structures, and W. C. Panarese, assistant research engineer structures, and in the field testing by L. E. Monson, formerly assistant structural engineer.

C. INSTRUMENTS

The electrical type instruments used in these tests to determine the stresses in the various parts of the girder spans consisted essentially of two 12-element oscillographs which recorded the stresses by means of electromagnetic or SR–4 wire resistance gages. A detailed description of the oscillographs, electromagnetic gages and auxiliary units is given in the AREA Proceedings, Vol. 46, 1945, page 201, and a description of the SR–4 wire resistance gages, with the necessary recording equipment, is given in the AREA Proceedings, Vol. 52, 1951, page 152. To secure readings on both the eastbound and westbound spans in the double-track territory, gages were mounted on both spans and a system of switches employed whereby the oscillographs recorded the effect of the trains on either track. The relative position of each locomotive wheel with respect to the center line of a span was indicated by the two solenoid marker units in each oscillograph through the use of a spring-type switch on the wheel position marker located on the rail. The speed of each locomotive was readily obtained from the oscillograms by determining the elapsed time for a locomotive of known wheel base to pass over the wheel position markers. With the locomotive speed known, the position of any wheel,

such as its location for maximum stress in the flanges or in the webs, could be readily ascertained.

The electromagnetic gages in all cases had a gage length of 2 in, while the length of the SR–4 gages varied from ¼ to 1 in. The strain gages were calibrated individually before the test runs were started and after completing the runs, and a close check was maintained on the sensitivity of each gage so that the relation between the strain in the steel and the amount of deflection of the oscillogram trace can be considered accurate to within a small percentage. In general, the gages located on the flanges of the girders had a sensitivity of 1 in deflection of the oscillograph trace equal to a stress of 10,000 psi, assuming a modulus of elasticity of 30,000,000 psi for the steel. This means that for a 2-in gage length, a 1-in deflection of the light trace on the oscillogram represents a unit strain of 0.000167 in the steel. The sensitivity of some of the other gages varied, depending on the magnitude of the stress to be determined, from 5000 psi to 20,000 psi per inch deflection of the oscillograph trace.

D. TEST SPANS AND LOCATION OF GAGES

35-Ft Deck Beam Span—Ballasted Timber Floor

This span, built in 1941, is part of a single-track structure near Persia, Ia., as shown by the top diagram of Fig. 8. The span consists of four 36 WF 230-lb beams per track with an overall length of 35 ft and with the beams spaced at 2 ft 6 in center to center of webs, as shown on Fig. 12. The beams are supported by a steel pile pier grillage, as shown on the left side of Fig. 4, and have a span length of 34 ft 2 in center to center of bearings. The 2 beams under each rail have top flange lateral bracing with the 4 beams diaphragmed together at the third points.

The floor is of the ballasted type, that is, the 6-in by 8-in ties supporting the 112-lb rails rest on about 6 in of crushed rock ballast. The ballast is supported by a solid 6-in timber floor resting directly on the smooth top flanges of the beams. There is no rail joint near the center of the span, but the north rail has a joint near the east end while the south rail has a joint near the west end of the span, as shown on Fig. 12. The center line of the track was off center ¾ in to the north at the center of the span, so the north beams were carrying 51.3 percent of the total load and the south beams 48.7 percent.

The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 101.4. A 2-in electromagnetic strain gage was erected on the center line of each beam at the center of the span, as shown in Fig. 12, to record the maximum tensile stresses in the individual beams.

40-Ft Deck Girder Spans—Open Timber Floor

The 2 test spans of this length, built in 1930, are part of a double-track structure near Genoa, Ill., as shown by the top diagram of Fig. 7 and the photograph on Fig. 1. The 2 spans, one under the westbound track and the other under the eastbound track, consist of girders 40 ft overall and 39 ft center to center of bearings, spaced at 7 ft 6 in center to center of webs, as shown in Fig. 9. Each span is braced laterally in both the plane of the top flange and bottom flange with cross frames located at the ends and center of the span. The girders have sliding bearings and are supported by concrete piers.

The floor is of the open type, that is, the 8-in by 11-in by 10-ft ties, spaced at 12-in centers and supporting the 130-lb rails, rest directly on the top flanges of the girders.

As shown on Fig. 9, the south rail of the westbound span has a joint 2 ft 2 in east of the center of the span while the north rail of the eastbound span has a joint 2 ft 7 in west of the center of the span. The center of the westbound track was off center ⅜ in to the south at the center of the span, so the south girder was calculated to carry 50.4 percent of the total load and the north girder, 49.6 percent. The center of the eastbound track was off center ½ in to the south, so the south girder was calculated to carry 50.6 percent of the total load and the north girder 49.4 percent. The capacity of the spans in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 98.5.

The strain gages were erected on various parts of the structure, such as the bottom flanges near the center of the spans, the web plates of both girders near the west end of the westbound span, and the web plates of both girders near the east end of the eastbound span; strain rosettes were placed on the web plates of both girders at the east end of the eastbound, as shown on Fig. 9.

46-Ft 8¾-In Deck Girder Span—Ballasted Timber Floor

This deck girder span was fabricated in 1913 but was relocated in the present single-track structure over Salt Creek near Elberon, Ia., in 1945, as shown by Fig. 3 and the lower diagram of Fig. 7. The girders are 46 ft 8¾ in overall and 45 ft 9¾ in center to center of bearings, and are spaced 8 ft center to center of web plates, as shown on Fig. 11. The top and bottom flanges are braced laterally by a single system of angles with 2 end and 2 intermediate cross frames. The west end of the span is fixed, and there is a sliding expansion bearing on the east end. Both bearings are supported by concrete piers.

The floor is of the ballasted type, that is, the track ties supporting the 112-lb rails rest on about 6 in of crushed rock ballast. The ballast is supported by a solid 7¾-in timber floor resting directly on the top flanges of the girders. The center of the track was ½ in north of the steel center line at the center of the span, so the north girder was calculated to carry 50.5 percent of the total load and the south girder 49.5 percent. The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 74.8.

The strain gages were erected on various parts of the structure, such as the lower flanges of the girders near the center of the span, the web plate of the south girder near the east and west ends of the span, 4 angles of the top lateral system, and on the members of the west end cross frame and 1 intermediate cross frame, as shown on Fig. 11.

55-Ft Deck Girder Spans—Open Timber Floor

The 2 test spans of this length, which were erected in 1930, are part of a double-track structure near Genoa, Ill., as shown by Fig. 1 and the top diagram of Fig. 7. The 2 spans, 1 under the westbound track and the other under the eastbound track, consist of girders 55 ft overall and 54 ft center to center of bearings, spaced at 7 ft 6 in center to center of webs, as shown in Fig. 9. The top and bottom flange of both spans are braced laterally with 4 by 4-in angles. Cross frames are located at the ends, center and intermediate points. The girders have sliding bearings and are supported by concrete piers.

The floor is of the open type, that is, the 8-in by 11-in by 10-ft ties, spaced at 12-in centers, supporting the 130-lb rails, rest directly on the top flanges of the girders. As shown on Fig. 9, the north rail of the westbound span has a joint 8 ft 9 in west of the

center of the span, and the north rail of the eastbound span has a joint 6 ft 3 in east of the center of the span. The center of the westbound track was on the center of the bridge at the center of the span, so both girders were calculated to carry equal loads. The center of the eastbound track was off center ¼ in to the south at the center of the span, so the south girder was calculated to carry 50.3 percent of the total load and the north girder 49.7 percent. The capacity of the spans in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 96.6.

The strain gages were erected on various parts of the structure, such as the bottom flanges near the center of the span, the web plates of both girders near the west end of the westbound span and the east end of the eastbound span, the top lateral bracing of the east end of the eastbound span, the cross frame at the east end of the eastbound span, the cross frame at the center of the eastbound span, and vertical gages on the web just under the top flange angle on the north girder of the eastbound span, as shown in Fig. 9.

85-Ft Through Girder Span—Ballasted Timber Floor

This through girder span, built in 1941, is part of a single-track structure near Persia, Ia., as shown by Fig. 4 and the top diagram of Fig. 8. The girders are 85 ft overall and 83 ft 6 in center to center of bearings, spaced at 16 ft 5 in center to center of webs, as shown in Fig. 12. The floor system consists of stringers and floorbeams, with the floorbeams spaced at 11-ft 10-in centers. The four 18 I 55-lb stringers per track are fastened to the webs of the built-up floorbeams by riveted connection angles, thus providing additional area to the lower flange in resisting flexure. The span is braced laterally by a double system of 6-in by ½-in steel plates in the plane of the lower flange, as shown in Fig. 12, which also provides additional flange area. The girders have fixed-bearing castings at the west end of the span and expansion bearings at the east end. The bearings are supported by a steel pile pier grillage, as shown on Fig. 4.

The floor is of the ballasted type, that is, the 6-in by 8-in by 8-ft track ties supporting the 112-lb rails rest on about 6 in of crushed rock ballast. The ballast is supported by a solid 6-in timber floor resting directly on the smooth top flanges of the stringers. As shown on Fig. 12, the north rail has a joint 9 ft 11 in west of the center of the span and the south rail a joint 7 ft 9½ in east of the center of the span. The center line of the track was off center ½ in to the north at the center of the span, so the north girder was calculated to carry 50.3 percent of the total load and the south girder 49.7 percent. The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 91.5.

The strain gages were erected on various parts of the structure, such as the bottom and top flanges of both girders at the center of the span, the web plate of the north girder near both ends, and on the lateral bracing in three west panels of the span, as shown on Fig. 12.

94-Ft 10-In Deck Girder Span—Open Timber Floor

This deck girder span, built in 1947, is part of a single-track structure over Cedar River near Cedar Rapids, Ia., as shown by Fig. 2 and the center diagram of Fig. 7. The girders are 94 ft 10 in overall and 92 ft 6 in center to center of bearings, with the girders spaced at 8 ft center to center of webs, as shown on Fig. 10. The top and bottom flanges are braced laterally by a single system with 6 by 6-in angles in the top and

5 by 5-in angles in the bottom system. The end and intermediate cross frames are spaced at about 15 ft. The east or expansion end is supported by a concrete abutment, while the west or fixed end is carried by a concrete cap encasing a steel bent down to a concrete pier.

The floor is of the open type, that is, the 8-in by 10½-in by 11-ft ties, spaced at 16-in centers, supporting the 112-lb rails, rest directly on the top flanges of the girders. The center of the track was off center ¼ in to the south at the center of the span, so the south girder was calculated to carry 50.3 percent of the total load and the north girder 49.7 percent. The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 98.9.

The strain gages were erected on various parts of the structure, such as the top and bottom flanges near the center of the span, the web plates of both girders near both the east and west ends, 2 panels of top lateral bracing at the east end and near the center of the span, on the cross frame members at the center of the span, and at the east end and on the web plate of the north girder at the east end directly under the flange plates, as shown on Fig. 10. In addition, a few runs were secured with rosette gages on the web plates near the east end of both girders (see Table 15).

107-Ft Through Girder Span—Ballasted Timber Floor

This through girder span, built in 1934, is part of a single-track structure near Weston, Ia., as shown by Fig. 5 and the lower diagram of Fig. 8. The girders are 107 ft overall and 105 ft center to center of bearings, spaced at 17-ft 6-in centers, as shown in Fig. 13. The floor system consists of stringers and floorbeams, with the floorbeams spaced at 13-ft 6½-in centers. The two 27 WF 102-lb stringers per track are fastened to the webs of the 36 WF 230-lb floorbeams by riveted connection angles, thus providing additional area to the lower flange in resisting flexure. The span is braced laterally by a double system of 4 by 4-in angles in the plane of the lower flange, as shown in Fig. 13, which also provides additional flange area. The span has fixed bearings at the west end and expansion bearings at the east end. The bearings are supported by concrete abutments.

The floor is of the ballasted type, that is, the 7-in by 9-in by 8-ft track ties supporting the 100-lb rails rest on about 6 in of crushed rock ballast. The ballast is supported by a solid timber floor resting directly on the smooth top flanges of the stringers. As shown on Fig. 13, the south rail has a joint 3 ft west of the center of the span. The center of the track was centered on the center line of bridge, so both girders were calculated to carry equal loads. The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 96.7.

The strain gages were erected on various parts of the structure, such as the top and bottom flanges of both girders near the center of the span, the web plates near the end and quarter point of the west end of both girders, on the lower flange of the stringers at the center of their span, on the lower flange of the center floorbeam just under the stringer connections, and on the lateral bracing in the end panel at the west end of the span and in a panel near the center, as shown on Fig. 13. In addition, a few runs were secured with the gages located on the cover plates near their ends, as shown on the left diagram of Table 11.

110-Ft 2-In Through Girder Span—Ballasted Timber Floor

This through girder span was fabricated and erected in the present single-track structure over Salt Creek, near Elberon, Ia., in 1945, as shown on Fig. 3, and in the general elevation of the entire structure appearing on the lower diagram of Fig. 7. The girders are 110 ft 2 in overall and 108 ft center to center of bearings, and are spaced at 19 ft 2 in center to center of web plates, as shown on Fig. 11. The floor system consists of stringers and floorbeams, with the 36 WF 230-lb floorbeams spaced at 13-ft 5-in centers. The two 24 WF 130-lb stringers per track are fastened to the webs of the floorbeams by riveted connection angles, thus providing additional area to the lower flange in resisting flexure. The lower flange of the span is braced laterally by a double system of two 3½ by 3½ by ½-in angles, as shown in Fig. 11, which also provides additional flange area. The span has fixed bearings at the east end and expansion rockers at the west end, both ends resting on concrete piers.

The floor is of the ballasted type, that is, the track ties supporting the 112-lb rails rest on about 6 in of crushed rock ballast. The ballast is supported by a 7¾-in solid timber floor resting directly on the smooth top flanges of the stringers. The center of the track was off center 1⅜ in to the north at the center of the span, so the north girder was calculated to carry 51.1 percent of the total load and the south girder 48.9 percent. The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 99.5.

The strain gages were erected on various parts of the structure, such as the upper and lower flanges of the girders near the center of the span, the web plate of the south girder near both the east and west ends, the lower flanges of a center and end floorbeam, the lower flanges of the stringers of the center panel, the lateral bracing in the end and center panels, and on the knee braces of the end and center floorbeams, as shown on Fig. 11.

140-Ft Through Girder Span—Open Timber Floor

This through girder span, with a timber approach span on each end, was built in 1946 and forms a single-track structure near Yorkshire, Ia., as shown by Fig. 6 and the center diagram of Fig. 8. The girders are 140 ft overall and 137 ft 6 in center to center of bearings, spaced at 19 ft center to center of webs, as shown on Fig. 14. The floor system consists of stringers and floorbeams, with the floorbeams spaced at 13-ft 9-in centers. The two 24 WF 120-lb stringers per track are fastened to the 36 WF 230-lb floorbeams by riveted connection angles, thus providing additional area to the lower flange in resisting flexure. The span is braced laterally by a double system of two 4 by 4 by ½-in angles in the plane of the lower flange, as shown on Fig. 14, which also provides additional flange area. The girders are fixed at the west end of the span, have expansion rollers at the east end, and are supported by concrete caps encasing steel pile piers.

The floor is of the open type, that is, the track ties supporting the 112-lb rails rest directly on the smooth top flanges of the stringers. The capacity of the span in flexure, using the gross section of the steel only and the present AREA design stresses and impact for steam locomotives, is Cooper E 106.0. The center line of track was centered on the center line of bridge, so both girders were calculated to carry equal loads.

The strain gages were erected on various parts of the structure, such as the bottom and top flanges of both girders near the center of the span, the web plates of both girders near the end and quarter point at the west end, the lower flanges of the two stringers in one panel, the lower flange of one floorbeam under the stringer connection, the lateral

bracing in the end panel at the west end of the span, and in a panel near the center, as shown on Fig. 14. In addition, a few runs were secured with the gages located on the cover plates near their ends, as shown on Table 11.

E. TEST TRAINS

The tests were conducted, as previously explained, under regularly scheduled trains, so the locomotive numbers were recorded as the trains passed over the bridge. The locomotives were then grouped for analysis of data according to their classes. A record was maintained of the amount of coal and fuel required to fill the tender of the steam locomotives at the next fueling stop past the bridge, and the necessary corrections were made to the recorded stresses.

The necessary information regarding all the diesel and steam locomotives used in these tests, such as axle weights, axle spacing and nominal wheel diameter was furnished by the mechanical department of the railroad, and these data are summarized on Fig. 15. The resultant weights producing dynamic augment were not calculated for the steam locomotives, but previous experience has indicated that these locomotives are very well balanced.

A general description of all the locomotives under which test records were obtained is as follows:

Diesel—Electric (2-axle)

The locomotives of this class are generally used in freight service with three or four units coupled together, and their axle weights and spacings are shown on Fig. 15. The ratings of these locomotives for the number of units and the particular units shown, followed by a uniform load of 3000 lb per track foot, in terms of Cooper loading for moment at the center of the span, vary from E 35.7 to E 40.9, as shown in Table 1.

Diesel—Electric (3-axle)

The locomotives of this class are generally used in passenger service with two units coupled together, and their axle weights and spacing are shown on Fig. 15. The ratings of these locomotives for the number of units and the particular units shown, followed by a uniform load of 2000 lb per track ft, in terms of Cooper loading for moment at the center of the span, vary from E 32.9 to 40.5, as shown in Table 1.

Steam Locomotive—Atlantic Type 4–4–2 (Class A)

The locomotives of this class are used in passenger service, and their axle weights and spacings are shown on Fig. 15. Readings under this class of locomotives were secured on only 2 spans, and the ratings of these locomotives, followed by a uniform load of 2000 lb per track foot, for moment at the center of the span, was E 42.6 for the 46-ft 8¾-in span and E 48.3 for the 110-ft 2-in span, as shown in Table 1.

Steam Locomotive—Mikado Type 2–8–2 (Class L2b)

The locomotives of this class are used in passenger service, and their axle weights and spacings are shown on Fig. 15. The ratings of these locomotives, followed by a uniform load of 3000 lb per track foot, for moment at the center of the span, vary from Cooper E 42.0 to E 52.6, as shown on Table 1.

Steam Locomotive—Northern Type 4–8–4 (Class S2 and S3)

The locomotives of these two classes are used in freight service, and their axle weights and spacings are shown on Fig. 15. The ratings of these locomotives, followed by a uniform load of 3000 lb per track foot, for moment at the center of the span, vary from E 62.8 to 67.8 for Class S2 and E 56.4 to 61.8 for Class S3, as shown on Table 1.

F. ANALYSIS OF FIELD RECORDS

Test Records

The test records or oscillograms were photographed on sensitized paper 10 in wide and 200 ft long. Each oscillogram was marked with the name of the railroad, bridge number and date. The oscillograph and run number, which were photographed on the record after each run, refers to the log of test runs, which shows the engine number, direction, approximate speed, type of train, and all other necessary information regarding the test run. The inclusion of all the test records, consisting of 1490 oscillograms for the 416 runs under steam locomotives and 329 runs under diesel locomotives, would make this report too voluminous. The oscillograms recorded during the tests on these girder spans are similar to the typical oscillograms shown on Fig. 16, which were secured on the 46-ft 8¾-in and 110-ft 2-in spans during the passage of an S2 class steam locomotive at 58.9 mph. All of the oscillograms are now on file in the AAR Research Center Laboratory at Chicago.

Reading the Oscillograms

In the analysis of the oscillograms it was first necessary to find the base lines representing zero stress. The first 2 or 3 in of the record on the left of the oscillograms were taken before the locomotive reached the span. The oscillographs were then started just as the locomotive reached the test span and continued until the locomotive and tender were off the span. The final 2 or 3 in of oscillograms on the right were then taken after the entire train had passed over the span. Base lines, representing zero stress, were then drawn from one side of the light trace for all the gages connecting the 2 no-load parts of the record. Where a complete study of the various impact factors in the girder were conducted, such as those in the flanges at the center of the span, light, dashed pencil lines, indicating upper and lower envelope curves, were drawn through the peaks of the oscillations, as shown for traces B11 and B12 on the 46-ft 8¾-in span and traces B9 and B10 on the 110-ft 2-in span (see Fig. 16). A solid line, called the mean stress curve, was then drawn midway between the upper and lower envelope curves. Since the mean stress curves for the slow locomotive speeds represent the static stress at the gage location for the different positions of the locomotive as it crossed over the span, it was necessary to determine the mean stress curves on all the slow-speed runs for those gage locations where the total impact effects were determined, such as the stringers, floorbeams and web plates. The impact effects were based on the average of the greatest mean stresses for the slow-speed runs of about 10 mph and under. The semi-amplitude of stress or the difference between the upper envelope curve and the mean stress curve is produced by irregularities of the track, and the effect of the resultant weights producing dynamic augment of the steam locomotive. At slow speeds of about 1 rps of the steam locomotive drivers, the effect of the resultant weights in producing oscillations is neglible, so the semi-amplitudes of stress are almost entirely due to track or wheel conditions. At higher speeds, the effect of the resultant weights producing dynamic augment in causing oscillations in the structure increases rapidly. At or near synchronous speeds the oscillations keep building up until they reach a maximum, which usually occurs at the time of maximum mean stress. It has been interesting to note from the oscillograms that the period of these oscillations coincides with the speed of the locomotive drivers in revolutions per second as theory predicts. An example of this can be seen on Fig. 16 where the period of oscillation in the 110-ft 2-in span was 0.245 sec, as indicated by traces B9 and B10.

Stress Corrections

Since the center of gravity of the air gap on the electromagnetic strain gages is 0.44 in from the base, the strains were correspondingly recorded on a plane 0.44 in from the surface of the steel. The stresses recorded in the top and bottom flanges of the girders were corrected by assuming that the stress is proportional to the distance from the neutral axis. The stresses recorded by the gages on the web plate were not corrected, as the average of the maximum simultaneous stresses recorded by the 2 gages was used for these readings, thus eliminating all bending effects in the web plates. This is clearly indicated on the typical oscillogram, Fig. 16, where the trace from the gages on one side of the web increases with a corresponding decrease in the trace from the gages on the opposite side. It was not necessary to correct the stresses recorded by the SR–4 wire gages, as these gages are a negligible distance from the surface of the steel.

Tabulation of Stresses

The mean, semi-amplitude and maximum galvanometer deflections from the gages on the center of the flanges and only the maximum deflections from the remaining gages, except those secured at slow speeds where the mean stresses are used for the recorded static stresses, were secured from the oscillograms and tabulated. The stresses were then determined from each gage by multiplying the galvanometer deflections by the individual stress factor determined from the calibration of the gages and based upon a modulus of elasticity of steel qual to 30,000,000 psi. The locomotive speed and the position of the first locomotive driver on the bridge with respect to the center line of span at the instant of recorded stress are also shown on the tabulation sheet.

Tables were then prepared for each test location showing the various static and dynamic effects at that location. The effects were tabulated according to locomotive class and in order of speed for each test span.

The tables containing all the essential test data taken from the oscillograms and entitled "Tabulation of Recorded Stresses" and "Analysis of Recorded Stresses" are on file in the AAR Research Center.

G. STATIC AND DYNAMIC EFFECTS

The oscillograph deflections, when multiplied by the proper stress factors for each gage circuit, were tabulated and then analyzed for the particular purpose of determining the magnitude of the static stresses, speed effects, roll effects, total impacts, maximum live load plus impact stresses, and other dynamic effects of the moving live loads. The results of this study are as follows:

1. Static Stresses

The recorded static stresses in the flanges and web plates of the stringers, floorbeams and girders were determined from the maximum mean stresses secured under slow-speed runs of approximately 5 mph for each locomotive class. The static stress in the flanges of the sections was the greatest mean stress recorded by the one gage on the member, but where the electromagnetic gages were used on the web plates, the static stress was determined from the greatest average mean stress of the two gages. The static stresses in the flanges of the 35-ft span were, of course, the greatest average mean stress of the two gages on the two beams under each rail. The calculated static stresses were based on the concentrated wheel loads, shown on Fig. 15, using the criteria for maximum stress and the gross section of the members. The exact position of the locomotive wheels which

produced the maximum recorded static stress was secured from the oscillograms, and it was found that this position usually agreed with the calculated position.

The use of concentrated wheel loads in calculating the static stresses is not an exact method, as it has been proved by rail stress measurements that the rail acts as a continuous beam on an elastic support, with the result that the pressure under the ties is more nearly a uniform load. However, the use of concentrated wheel loads is common practice in the design office and results in only a 2 or 3 percent error in the longer girder spans and 12 to 15 percent error in the shorter spans. The calculated stresses were also based on the gross section of the member, as the gages were all located on a section between rivet holes or any stress raisers. No consideration was given to any composite action of the stringers or lateral bracing in calculating the moment of inertia of the sections.

a. Flange at Center of Girder

The comparison of the recorded and calculated static live-load stresses and the resulting stress factors, or the ratio of the recorded to the calculated stresses, in the flanges of each girder at or close to the center of the span, are shown in Table 2 and 3 for both the diesel and steam locomotives. All recorded stresses shown were determined from the gages on the lower flanges, except those for the 110-ft 2-in span which are based on the upper flange readings. The static stresses recorded in each girder and the average of the two girders are shown in Cols. 4, 5, and 6 of this table, while the calculated stresses are shown in Col. 7. For example, the recorded static stress in the 35-ft span under four 2-axle diesel locomotives varied from 2.95 ksi to 3.07 ksi, as shown in Col. 6, as compared to the calculated static stress of 3.28 ksi, shown in Col. 7. The stress factors for each static test run are shown in Col. 8, while the average stress factors for all the runs secured under the 2-axle and 3-axle diesel locomotives are shown in Col. 9. For example, the stress factors for the 8 diesel locomotives crossing over the 35-ft beam span at slow speeds of about 5 mph varied from 0.90 to 0.97, with an average of 0.93. The stress factors for the 8 steam locomotives crossing over the 35-ft span varied from 0.84 to 1.13, with an average of 0.99.

It can be seen from Tables 2 and 3 that there is considerable variation between the recorded and calculated static stresses, with a corresponding variation in the stress factors. The greatest variation between the stresses was found in the 40-ft westbound girder span under the diesel locomotives where an average stress factor of only 0.72 was determined, which means that the recorded static stresses were only 72 percent of those calculated. Part of this variation could be due to the use of concentrated wheel loads in the calculations and part due to the redistribution of the locomotive axle loads. Experience in weighing locomotive axles has proved that considerable variation in axle loads takes place when the axles change elevation relative to each other. As the span deflects under live load, the center axles become lower than the end axles; consequently, part of the load on these axles may be transferred forward and backward to the end axles. The uneven support of the rails will also change the elevation of the axles relative to each other, thus changing the loads carried by each axle.

The effect of the stringers and lateral bracing in reducing the stresses in the flanges is indicated by the average stress factors for the through girder spans. The stress factors for the 85-ft, 107-ft and 140-ft through girder spans varied from 0.74 to 0.90 (see Col. 9), but the stress factors for the 94-ft 10-in deck span were 0.98 for the diesel and 0.88 for the steam locomotives. Another interesting observation is the stress factor of 1.04 for the 110-ft 2-in through girder span, which was determined from the gages on

the upper flange where stresses greater than in the lower flanges would be expected because of a downward shift in the neutral axis of the girders produced by the composite action of the stringers, lateral bracing and lower flange of the girders.

b. Web at End of Girder

The comparison of the recorded and calculated static live-load stresses in the web plates near the ends of the girders and the resulting stress factors are shown in Table 4 for both the diesel and steam locomotives. The stress factors for 7 of the spans are based on average readings secured on the web plates of both the north and south girders, but on 3 of the spans, namely, the 46-ft 8¾-in, 85-ft, and 110-ft 2-in spans, the average factors shown are for one girder only. It is evident that the relation between the recorded and calculated stresses in the web plates is about the same as that found for the stresses in the flanges at the center of the span, as the stress factors for the webs averaged 0.80 for 53 static runs as compared with an average of 0.81 for 78 static runs for the flanges. The previous arguments for the low stress factors in the flanges at the center should not apply to the web stress factors as the shears at the end of the span should not be materially influenced by load distribution to the axles or any difference between concentrated axle loads or uniform load.

c. Web at Quarter Point of Girder

The comparison of the recorded and calculated static live-load stresses in the web plates near the quarter points of the 107-ft and 140-ft girder spans and the resulting stress factors are shown in Cols. 4 to 9, incl., of Table 5 for both diesel and steam locomotives. While the recorded and calculated static stresses in the webs at this point are appreciably lower than those at the ends, as a result of the uniform web thickness, it can be seen that the stress factors are about the same.

d. Stringers and Floorbeams

The recorded and calculated static live-load stresses in the lower flanges of the stringers and floorbeams of the 107-ft, 110-ft 2-in, and 140-ft spans and the resulting stress factors are shown in Cols. 10 to, 25 incl., of Table 5. Considerable variation was found in the stress factors, and it can be seen that average values ranging from 0.73 to 1.03 were obtained for the stringers and center floorbeams. Low stress factors were found for the one end floorbeam tested.

2. Speed Effect

The increase or decrease in the average mean simultaneous stresses recorded in the 2 girders of each test span resulting from the locomotive passing over the bridge at increasing speeds has been termed speed effect. This speed effect could be due to the centrifugal force resulting from the loaded axles running over the deflected span, or to the variation in the axle loads resulting from the accelerations of the unsprung weight of the locomotive during the vertical oscillations of the sprung weight. Since this could result in a decrease in the axle loads at times as well as an increase, it can be seen that negative speed effects are not uncommon. A negative speed effect implies that the average mean simultaneous stress recorded for the 2 girders was less than the average recorded static stress.

The measured speed effects, in percent of the measured static stresses secured at speeds less than 10 mph, are shown in the upper left diagrams of Figs. 17 to 31, incl., for the 2-axle and 3-axle diesel locomotives on the 40 to 140-ft spans. The measured speed effects for the 4 classes of steam locomotives are shown in the upper left diagrams of Figs. 32 to 56, incl. The speed effects for the diesels varied from + 38 percent on the 40-ft eastbound deck girder span (Fig. 17) to — 26 percent on the 40-ft westbound deck

girder span (Fig. 19), while those for the steam locomotives varied from + 63 percent on the 40-ft eastbound span (Fig. 32) to — 18 percent on the 46-ft 8¾-in span (Fig. 36). As previously mentioned, a total of 745 test runs were obtained over the 6 bridges, and a study of the speed effect value, shown on Figs. 17 to 56, incl., reveals that a total of 712 individual readings at speeds above 10 mph were recorded on the 10 spans varying in length from 40 to 140 ft, and that 276 readings were diesel while 436 were steam. Of the 276 readings for which speeds effects were measured under diesel power on 8 spans, 166 readings produced positive speed effects and 115 of these ranged from only 0 to + 10 percent. The remaining 110 readings for the diesels produced negative speed effects, of which 91 were in the 0 to — 10 percent range. Thus, 76 percent of the 276 readings under diesel power were within a range of plus or minus 10 percent of the recorded static stress. Of the 436 readings for which speed effects were measured under steam locomotives on 10 spans, 300 readings produced positive speed effects, of which 227 ranged from 0 to + 10 percent. The other 136 runs for the steam power produced negative speed effects, of which 103 runs were in the 0 to — 10 percent range. Thus, 76 percent of the 436 readings under steam power were within a range of plus or minus 10 percent of the recorded static stress. It appears that the magnitude of the speed effects caused by the diesel locomotives and those caused by the steam locomotives, as a percentage of the recorded static stresses, are about equal.

3. Roll Effect

Roll effect has been defined as an increase in mean stress in one girder with a corresponding simultaneous decrease in the mean stress in the other girder of the same span. This phenomenon is undoubtedly due to the spring-borne weight of the locomotive oscillating about a longitudinal axis. Roll effect is probably set up not only by track inequalities, but also by the weaving or nosing of the locomotive from side to side.

The magnitude of the increase in stress in one girder was found by subtracting the average simultaneous mean stress of both girders from the maximum mean stress. Any variation of the recorded mean stresses due to "eccentricity of track from center line of bridge" was corrected out, so that the increase in mean stress in one girder with a corresponding decrease in the other girder was due only to rolling of the locomotive. The increase in pressure on the rail which would produce the recorded difference in stress in the girders, in percent of the recorded static stress, is shown in the lower left diagrams of Figs. 17 to 31, incl., for the diesel locomotives, and Figs. 32 to 56, incl. for the steam locomotives. For example, when the 2-axle diesel passed over the 40-ft eastbound deck girder span at 74 mph (see Fig. 17), the recorded mean stress in one of the girders at the center line of span was found to be 6.7 percent greater than the average mean stress in both girders, due to an increase in pressure on the rail of 10 percent, as shown by the solid circle for this particular run.

A study of the roll effect diagrams on Figs. 17 to 56, incl., indicates that the roll effect was measured under 318 diesel locomotives and 493 steam locomotives, or a total of 811 readings on 10 spans varying from 40 to 140 ft in length. The roll effect, as a percentage of the recorded static stresses, appears to be about the same for both diesel and steam locomotives. Under the diesel locomotives, only 18 out of 318 readings, or 5.7 percent of the total roll effects secured on 8 spans, exceeded the present AREA allowance, while for the steam locomotives only 35 out of a total of 493 readings on 10 spans, or 7.1 percent, exceeded the present AREA allowance. The majority of the roll effects that exceeded the AREA allowance for the diesels occurred on the 107-ft and 140-ft spans (Figs. 29, 30 and 31). Out of the 10 readings recorded on the 107-ft through girder

span under 3-axle diesels, roll effects for 7 runs exceeded the AREA allowance of 20 percent. It is interesting to note that all of these values were recorded at speeds of about 90 mph (see Fig. 30). The majority of the values that exceeded the AREA allowance for roll effect under the steam locomotives occurred on the 40-ft eastbound and westbound spans, the 110-ft 2-in span, and the 140-ft span (see Figs. 32, 34, 50, 54 and 55).

There is considerable variation in the rolling effect found in these 10 spans and there does not appear to be any relation between this variation and locomotive speed.

4. Track Effect—Diesel Locomotives

Vertical vibrations induced in a railroad bridge by the passage of a diesel locomotive are undoubtedly caused by wheel and track irregularities. Wheel irregularities could consist of flat spots, out-of-round wheels and eccentric mountings, while track irregularities usually result from hard and soft spots in the ballast, battered rail joints or uneven bridge tie wear.

The track-effect stresses or stress semi-amplitudes of vibration as read from the oscillograms for the 8 girder spans are plotted on the upper right diagrams of Figs. 17 to 31, incl., for the 2-axle and 3-axle diesels operating over a complete range of speeds from 2 mph up to 97 mph. The calculated natural loaded frequency of vibration *(n)* of these spans, in vibrations per second, is also shown on these figures. It is evident from a study of these track-effect diagrams that there is no particular critical speed for the diesel locomotives where the track-effect stresses become a maximum; however, the stresses do exhibit an increase with an increase in speed. It should be kept in mind that the wheels of the diesel locomotive do not have any unbalanced weights such as the steam locomotive, thus the forces necessary to excite vibrations in the span must be produced by the uneven track, flat spots or out-of-round wheels.

Taking into account the variations which may exist in the condition of the wheels of many diesel locomotives, it is understandable why so much scatter is present in the track-effect stresses on many spans, such as the 40-ft westbound span shown in Fig. 19. However, on this span the maximum semi-amplitudes under the 2-axle diesels were recorded at speeds between 50 and 60 mph, and at these speeds the wheels came onto the span or crossed over a tight tie plate at a frequency of 8.13 to 9.75 times per second, which is lower than the natural loaded frequency of the span shown in the lower left corner of Fig. 19. A frequency of 11.8 vps would indicate a speed of about 69 mph.

The track effects, expressed as a percentage of the recorded static stresses for each girder of each span, are shown in the lower right diagram of Figs. 17 to 31, incl., for the 2-axle and 3-axle diesels. The 3-axle diesels produced greater track-effect percentages than the 2-axle diesels on all spans over which both types of diesels operated. From a total of 318 readings for all diesels operating on 8 test spans, 636 track-effect stresses were read from the oscillograms for the north and south girders. A study of the track effects indicate that 83 percent of the values are between 0 and 10 percent of the recorded static stress, while 15 percent are between 10 and 20 percent of the recorded static stress and only 2 percent of the 636 readings exceeded 20 percent of the recorded static stress.

5. Track and Hammer-Blow Effect—Steam Locomotives

The vertical vibrations produced in a railroad bridge under passage of a steam locomotive are undoubtedly caused by a combination of wheel and track irregularities and the periodic disturbing forces of the counterweights. This disturbing force, or hammer blow, of the steam locomotive is due to the centrifugal force of the unbalanced weights

on the revolving driving wheels. It is possible that in some cases the condition of the track would tend to counteract the vibrations in the span due to hammer blow. In other cases the vibrations due to track conditions might augment the vibrations in the span due to hammer blow. Since there is no way to determine the separate effects in tests of this type, the only alternative is to report on their combined effect.

The total track plus hammer-blow stresses or stress semi-amplitudes of vibration as read from the oscillograms for the 10 spans are plotted on the upper right diagrams of Figs. 32 to 56, incl., for the 4 classes of steam locomotives. These diagrams cover a complete range of speeds from 2 mph up to and including 90 mph. The calculated stresses in the girder flanges caused by the resultant weights producing dynamic augment or hammer blow of the locomotive drivers have not been computed for these tests, as it was known that the Milwaukee Road locomotives used were well balanced.

The calculated natural loaded frequency of vibration *(n)* of these spans in vibrations per second and in miles per hour for the nominal driver diameters is shown on each figure for the particular locomotive class and span. It can be seen from the diagrams that synchronous speed was attained by at least one class of steam locomotives operating over the 107-ft, 110-ft 2-in, and 140-ft spans. A study of the total track plus hammer-blow stress diagrams reveals that there is an apparent magnification of the stresses at or near synchronous speed on some spans, notably the 140-ft through girder span (see Figs. 54 and 55).

The track plus hammer-blow effects, expressed as a percentage of the recorded static stresses, are shown in the lower right diagrams of Figs. 32 to 56, incl. It can be seen from a study of these diagrams that the track plus hammer-blow effects recorded under the Class L2b locomotives were considerably higher than those recorded under the Class A, S2 or S3 locomotives, and that they amount to about 30 percent of the recorded static stresses on the 46-ft 8¾-in span and 40 percent on the 110-ft 2-in and 140-ft spans.

In general, there does not appear to be much difference in the track plus hammer-blow effects recorded in the various spans for the Class A, S2 and S3 locomotives, nor does there appear to be any difference in the magnitude of the recorded track plus hammer-blow effects induced by these 3 classes on the same span (see Figs. 36, 38 and 39 for the 46-ft 8¾-in span and Figs. 50, 52 and 53 for the 110-ft 2-in span).

From a total of 493 readings for all steam locomotives operating on 10 spans, 986 track plus hammer-blow stresses were read from the oscillograms for the north and south girders. A study of the track plus hammer-blow effects indicates that about 68 percent of the 986 values obtained are between 0 and 10 percent of the recorded static stress, 24 percent are between 10 and 20 percent of the recorded static stress, and only about 8 percent exceed 20 percent of the recorded static stress.

6. Total Impacts

Total impacts recorded in either the lower or upper flanges of the girders close to the centers of the spans, in the web plates close to the ends of the spans, and in the web plates close to the quarter points of the spans, and under the various locomotive classes at a full range of speeds, are shown on the diagrams of Figs. 57 to 79, incl. The total impact percentage in each test run for a particular speed is the increase in stress in the member over the average mean stress occurring at a slow speed for the same locomotive class. The total impacts are the combinations of (1) speed effect, (2) roll effect, and (3) track and hammer-blow effects, although it would be only by remote chance that the maximum for all effects would occur simultaneously.

a. Flanges at Centers of Spans

The total impact percentages resulting from the 329 diesel locomotives crossing the 10 girder spans and 1 beam span, as determined from the tests with the gages on the lower flanges of all the spans, except the 110-ft 2-in span where the gages were on the upper flanges, are shown by the upper diagrams of Figs. 57 to 67, incl. No test runs were secured under diesel locomotives on the 46-ft 8¾-in span (Fig. 60) and 110-ft 2-in span (Fig. 66), while test runs under only the 2-axle diesels were secured on the 140-ft span (Fig. 67). These diagrams also show the impact percentage as computed by the AREA design specification for rolling equipment without hammer blow.

The diagrams of total impacts show that there was considerable scatter of impact values even at the same speeds, indicating that not all of the impact effects were a maximum at the same time. In several of the bridges the total recorded impacts under the diesel locomotives exceeded the design specification allowance, as can be seen from the top diagrams of Figs. 58, 59, 63, 65, 66 and 67. The natural loaded frequency of these spans under the particular locomotive class, computed from the equation

$$n = \sqrt{\frac{12.4}{d + D}}$$

where d is the dead-load deflection and D is the live load deflection in inches, is shown in the lower left hand corner of each diagram. For example, the loaded frequency of the 40-ft span under the 2-axle diesel is 11.2 vps, while that under the 3-axle diesel is 10.1 vps. The spacing of the wheels on the 2-axle diesel is 9 ft, and at 72 mph, the speed at which the maximum impact was recorded, the wheels crossed over a tight tie plate or came onto the span at a frequency of 11.7 vps, which is in good agreement with the natural frequency of 11.2 vps corresponding to 68.5 mph.

The total impact percentages resulting from the 416 steam locomotives crossing the spans are shown by the lower diagrams of Figs. 57 to 67, incl. On those bridges where no test runs were secured under diesel locomotives, additional data were secured under other steam locomotive classes, and total impacts under these locomotives are shown on the upper diagrams. These diagrams also show the impact percentage, as computed by the AREA design specification, for rolling equipment with hammer blow. It can be seen from these diagrams that all the recorded values were below the specification value, except for one value on the 40-ft eastbound span under a Class S2 locomotive at about 5.6 rps or 75 mph (see Fig. 58), 1 value on the 110-ft 2-in span under a Class L2–b locomotive at about 3.1 rps or 34 mph (see Fig. 66), and 3 values on the 140-ft span under a Class L2–b locomotive at about 3.1 to 3.5 rps or 34 to 39 mph (see Fig. 67).

The loaded frequencies of the spans under the steam locomotives are shown on the lower left hand corner of each figure, and it can be seen that these frequencies are above the actual operating speeds of the locomotive over the 35-ft and 40-ft spans. A considerable number of runs were secured under the Class S2 and S3 locomotives on the 107-ft, 110-ft 2-in and 140-ft spans at or near the loaded frequency of the span without any apparent large increase in the total impacts (see Figs. 65, 66 and 67).

b. Webs at Ends of Girders

The total impact percentages resulting from the diesel locomotives crossing the test spans, as determined from the tests with the gages on the girder webs close to the ends of the spans, are shown on the upper diagrams of Figs. 68 to 77, incl., except on Figs. 70 and 76, as no test runs were secured under diesel locomotives on these spans. These diagrams also show the impact percentage as computed from the current AREA design specification, and it can be seen that the maximum impacts on several of the spans are

above or close to the calculated values. In general, these diagrams indicate that the maximum impacts under the diesel locomotives increased with an increase in speed, but there is still a considerable scatter of the results indicating that not all the impact effects were a maximum at the same time.

The total impact percentages resulting from the passage of steam locomotives over the test spans are shown on the lower diagrams of Figs. 68 to 77, incl. The diagrams also show the impact percentages as computed by the AREA design specification for rolling equipment with hammer blow. In general, the recorded impacts are smaller than the calculated values, except for those on the 46-ft 8¾-in span under the Class A locomotive (see Fig. 70), the 110-ft 2-in span under both Class S2 and Class S3 locomotives (see Fig. 76), and the 140-ft span under the Class L2–b, S2 and S3 locomotives (see Fig. 77).

A comparison of the impacts determined from the gages on the flanges of the girders (Figs. 57 to 67) with those determined from the gages on the webs of the girders (Figs. 68 to 77) indicate that, in some cases, higher impacts occurred in the webs than in the flanges. For example, referring to the impacts in the flanges of the 46-ft 8¾-in span as shown on Fig. 60, and those in the webs as shown on Fig. 70, and it can be seen by comparing the impacts under the same class of locomotives that the web impacts are higher.

c. Webs at Quarter Points of Girders

The total impact percentages recorded in the webs at the quarter points of the 107-ft and 140-ft spans under the diesel and steam locomotives, as well as the impact percentages as computed from the current AREA design specification, are shown on the diagrams of Figs. 78 and 79, and it can be seen that the recorded impacts under the 2-axle diesels are considerably larger than the calculated values on the 107-ft span, while those under both the diesel and steam locomotives exceed the calculated values on the 140-ft span. As previously mentioned, the impacts in the webs at the ends of the girders were also larger than the calculated values on these spans. This comparison of relative impacts at the quarter points and ends of the spans is of minor importance in girder spans, as there is usually ample web section at the quarter point; however, the quarter-point impacts are of importance in the web members of truss spans.

7. Maximum Stresses

The maximum live-load plus impact stresses recorded in the upper and lower flanges, web plates at the ends of the spans, web plates near the quarter points and later bracing of the spans under the various locomotive classes at a full range of speeds are shown in Figs. 80 to 102, incl., and Tables 12 and 13. As previously mentioned, the gages were all located on the gross section of the members to keep away from any effects of stress concentration around rivet holes, so all calculated stresses shown are based on the gross section of the members.

a. Flanges at Centers of Girders

The maximum stresses recorded in the flanges of the girders close to the centers of the spans under the passage of the diesel locomotives are shown on the upper diagrams of Figs. 80 to 90, incl., except for the 46-ft 8¾-in span (Fig. 83) and 110-ft 2-in span (Fig. 89), where only test runs under steam locomotives were secured. These diagrams also show the recorded and calculated static stresses, as taken from Tables 2 and 3, and the calculated maximum stresses using the current AREA design specification impact for rolling equipment without hammer blow. It can be seen that the recorded maximum

stresses are below those calculated, although in the 107-ft span they are only slightly below the calculated (see Fig. 88).

In general, there appears to be an increase in the recorded stresses with an increase in speed of the locomotive, but this increase in stress is also accompanied by a greater scatter of the magnitude of the stresses. It can be seen from Fig. 88 that while some of the stresses under the 2-axle diesel at 50 to 60 mph are close to those calculated, some of the other runs at the same speed range produced stresss below the calculated or recorded static stress. This phenomenon is undoubtedly the result of a heavy rolling of the locomotive about a longitudinal axis, accompanied by a vertical acceleration of the sprung weight of the locomotive or of a low track and hammer-blow effect at that particular time.

While the maximum impact under the diesel locomotives was 64 percent, as recorded in the 40-ft eastbound span under the 2-axle diesel crossing over the bridge at 72 mph (see Fig. 58), the recorded maximum stress of 4.6 ksi in this span is appreciably below the calculated value of 6.2 ksi as a result of the recorded static stresses being only 70 percent of the calculated static stress (see Table 2 and Fig. 81).

The maximum stresses recorded in the flanges of the girders close to the centers of the spans under the passage of the steam locomotives are shown by the lower diagrams of Figs. 80 to 90, incl., with Figs. 83 to 89 having both upper and lower diagrams for steam locomotives. These diagrams also show the recorded and calculated static stresses, as taken from Tables 2 and 3, and the calculated maximum stresses, using the current AREA design specification impact for rolling equipment with hammer blow.

In general, the recorded maximum stresses are below those calculated, except in the 110-ft 2-in span (Fig. 89) where several values are above the calculated for the Class L2–b locomotives and only slightly below for the Class A locomotives. It can be seen from Fig. 66 that only one impact value was recorded greater than the AREA design specification value; however, the recorded static stresses in this span under all four locomotive classes were somewhat greater than the calculated, resulting in the higher maximum stresses. As previously mentioned, the gages were located on the upper flanges of this span, and since the floor system consists of stringers and floorbeams it is reasonable to expect that the compressive stresses in the top flange would be greater than the tensile stresses in the lower flange.

b. Webs at Ends of Girders

The maximum stresses recorded in the web plates, at an angle of 45 deg with the vertical, under the passage of the diesel locomotives are shown by the upper diagrams of Figs. 91 to 100, incl., except for Figs. 93 and 99, as no test runs were secured under diesel locomotives on these spans. These diagrams also show the recorded and calculated static stresses, as taken from Table 4, and the calculated maximum stresses, using the current AREA design specification impact for rolling equipment without hammer blow.

The stresses were, in general, well below the calculated values, except under the passage of the 2-axle diesel locomotives over the 107-ft and 140-ft spans (Figs. 98 and 100), where one stress on each span was just under the calculated value. As previously pointed out, several impact values under the diesel locomotives exceeded the calculated values on about half the test spans, but since the recorded static stresses are below those calculated the maximum stresses are lower.

The total maximum stresses resulting from the steam locomotives crossing the test spans, as determined from the tests with the gages on the web plates at the end of the spans, are shown on the lower diagrams of Figs. 91 to 100, incl., and on the upper diagrams of Figs. 93 and 99. These diagrams also show the recorded and calculated static

stresses, as taken from Table 4, and the calculated maximum stresses, using the current AREA design specification impact for rolling equipment having hammer blow.

It can be seen from the diagrams that the maximum stresses were well below those calculated, except those recorded under the Class A locomotives on the 46-ft 8¾-in span (Fig. 93) and those under the Class A and Class S2 on the 110-ft 2-in span (Fig. 99). The maximum stresses in the webs were recorded in the 46-ft 8¾-in span under the passage of the Class S2 locomotives at speeds of about 50 mph (Fig. 93), and this recorded value of 7.60 ksi is considerably below the permissible value for web stresses.

c. Webs at Quarter Points of Girders

The maximum live-load plus impact stresses produced by the diesel and steam locomotives in the girder webs close to the quarter points of the 107-ft and 140-ft spans, as well as the calculated and recorded static stresses and the calculated maximum stresses, are shown on the diagrams of Figs. 101 and 102. In general, there is fair agreement between the recorded and calculated maximum stresses at the higher speeds, with the stresses under the 2-axle locomotives being about equal to those calculated on the 107-ft span and several values exceeding the calculated on the 140-ft span. The recorded stresses under the steam locomotives are below the calculated values on the 107-ft span, but one value exceeds the calculated on the 140-ft span; however, these stresses are considerably lower than the web stresses at the ends of the girders, as would be expected, on account of the uniform web thickness.

d. Lateral Bracing of Girder Spans

The maximum direct stresses recorded in the lateral bracing and cross frames of the 46-ft 8¾-in and 94-ft 10-in deck spans and in the lateral bracing of the 85-ft, 107-ft, 110-ft 2-in and 140-ft through spans under the various diesel and steam locomotives, are shown on Tables 12 and 13 for the full range of speeds. When only two electromagnetic gages were used, such as shown for the top laterals of the 46-ft 8¾-in span (Table 12), they were located near the neutral axis of the member so that only direct stresses were recorded. When three SR–4 wire gages were used, such as shown for the laterals of the 107-ft span (Table 12), they were located on the 3 corners of the member; however, the stresses shown in the table are the algebraic average of the 3 gages, so they can be considered the direct stresses in the members.

In general, the direct stresses in the laterals ranged from a tensile stress to a compressive stress during the passage of the locomotive, and several cycles of this reversal usually took place during one run. The maximum range in stresses occurred at Section C–C of the end cross frame on the 46-ft 8¾-in deck span where the stresses ranged from about 4.9 ksi tension to about 6.6 ksi compression, a range of about 11.5 ksi. The stresses measured with the 3 SR–4 wire gages on the 3 corners of the angles indicated that considerable bending was taking place in these angles when they were connected by only one leg to the lateral plate. For example, when the direct stress in the lateral angle, as determined by the average of the stresses on the 3 corners, indicated compression, the outstanding leg of the angle would be in tension while the stress in the other leg would be 2 or 3 times the average stress.

The stresses recorded in most of the lateral bracing members appear to increase with an increase in speed, and in most of the members the stresses recorded under the diesel locomotives are smaller than those recorded under the steam locomotives, although this reduction in stress under the diesel locomotives is not as great as that found in the flanges.

A comparison of the recorded and calculated maximum direct stresses in the top laterals of the 46-ft 8¾-in and 94-ft 10-in deck girder spans, and in the bottom laterals

of the 85-ft, 107-ft, 110-ft 2-in and 140-ft through girder spans, is shown in Table 14. For example, the maximum direct stress recorded in the end top lateral angle of the 94-ft 10-in deck girder span, Section A–A, under Class "S2" locomotives is 1.60 ksi tension, and this stress occurred at a speed of 23.4 mph. The corresponding lateral load applied at a panel point to cause this stress of 1.60 ksi in the end top lateral angle would be 10.2 kips, as shown under "Corres. Lateral Load". The calculated AREA stress in this member, using the 20 kip design allowance for nosing of the locomotive, is 3.15 ksi, as shown under "AREA—Nosing". The calculated stress for transverse shear in the compression flange is 0.99 ksi, as shown under "AREA—Transv. Shear", with a total AREA design stress in the angle of 4.14 ksi tension or compression. No allowance was made for wind on the structures since there was no appreciable wind blowing at the time of the tests.

The greatest maximum stress in the top lateral bracing of the bridges tested was recorded under a Class S3 locomotive at 53.4 mph on the 46-ft 8¾-in span. This stress was 4.64 ksi compression, which would correspond to a lateral force of 22.4 kips at the center of the span. The greatest maximum stress in the bottom laterals was 7.20 ksi tension and was recorded in the third panel bracing of the 85-ft span under passage of a Class S3 locomotive at 74.0 mph. This stress would correspond to a lateral force of 30.6 kips applied at the third panel point of the span. It should be noted that for this particular span it was assumed that lateral bracing of this type section could not take compression, and this assumption was employed in the calculated stresses.

It can be seen that only two values of recorded maximum stress in the top laterals resulted in corresponding lateral loads in excess of the AREA nosing load of 20 kips, and both readings occurred at Section B–B of the 46-ft 8¾-in deck girder span. With the addition of the calculated transverse shearing stress to the calculated AREA nosing stress, the recorded maximum stresses were less than the total calculated stresses for the top laterals in all cases. However, in the bottom laterals many maximum stresses were recorded which exceeded the calculated AREA nosing stress. For example, all the recorded maximum stresses at Sections C–C and D–D on the 110-ft 2-in and 140-ft through spans exceeded the calculated nosing stresses, and the corresponding lateral loads for these sections varied from 20.7 to 37.8 kips. Two values for recorded maximum stress exceeded the calculated stress at Section C–C on the 85-ft span and Section D–D on the 107-ft span.

8. Comparison of Top and Bottom Flange Stresses

Strain gages were placed on both the top and bottom flanges of the 85-ft, 94-ft 10-in, 107-ft and 140-ft girder spans, as shown on Figs. 10, 12, 13, and 14, and several test runs were secured with the gages at these locations. The maximum simultaneous stresses recorded by these gages under several test runs, selected at random from the higher speed runs for the various locomotive classes, are shown in Table 6 for the 4 spans.

The maximum stresses recorded in the top flanges of the north girders are shown in Col. 5 of Table 6, while the simultaneous stresses in the bottom flanges of the same girders are shown in Col. 6. The variation between the top and bottom stresses and the percent variation from the bottom flange stress are shown in Cols. 7 and 8. For example, when the 2-axle diesel locomotive crossed over the 85-ft through plate-girder span at 57.2 mph, a compressive stress of 3.37 ksi was recorded in the top flange of the north girder simultaneously with a tensile stress of 3.23 ksi in the lower flange. It can be seen

that the top flange stress was 0.14 ksi, or 4.3 percent greater than the lower flange stress. Similar data secured on the south girders are shown in Cols. 9 to 12, incl.

As previously mentioned, the floor systems of the through plate-girder spans consisted of stringers and floorbeams, and the effect of the composite action between stringers and lower flanges is evident from the data in this table. For example, the average stress in the top flanges of the 85-ft through plate-girder span under the 12 runs shown in Table 6 was 22.9 percent greater than the average stress in the bottom flanges, but the average stress in the top flanges of the 94-ft 10-in deck plate-girder span under the 12 runs shown was only 96 percent of the bottom flange stress. The difference between the top and bottom flange stresses for the 107-ft and 140-ft through girder spans was not as great as that for the 85-ft span, but the average stresses in the top flange were still greater than those in the lower flange.

9. Variation of Stresses Across Flanges

The stresses at the center and outside edges of the top flanges of both girders of the 85-ft and 110-ft 2-in through plate-girder spans and in both the top and bottom flanges of the 107-ft and 140-ft through plate-girder spans were determined from the gages located as shown by the diagrams on Tables 7, 8, and 9. The maximum simultaneous stresses recorded by these gages, under several runs for each locomotive class over a wide range of speeds, are shown in these tables.

The maximum stresses recorded at the center of the top flange of the north girders of the 85-ft and 110-ft 2-in spans are shown in Col. 5 of Table 7, while the simultaneous stresses on the edges are shown in Cols. 6 and 7. The average of the stresses recorded on the edges is shown in Col. 8, and the difference between the maximum edge stress and the average of the two edge stresses is shown in Col. 9. A positive sign on the stress indicates that the stress at the inner edge is greater than the average stress. The difference between the maximum edge stress and the average edge stress, as a percentage of the average edge stress, is shown in Col. 10. For example, the passage of a 2-axle diesel over the 85-ft span at 48.4 mph produced a compressive stress at the center of the flange of 2.91 ksi and simultaneous compressive stresses of 3.16 ksi on the outside edge and 3.57 ksi on the inside edge, with an average of 3.37 ksi. The stress on the inside edge was 0.20 ksi, or 5.9 percent greater than the average edge stress.

It can be seen from Tables 7, 8, and 9 that the cross bending in both the top and bottom flanges was quite small for all the spans tested, with the maximum values being recorded in the top flange of the south girder of the 107-ft span. In this flange the average bending was + 6.3 percent, the positive sign indicating that the stress on the inside edge was greater than the average stress. However, the deflection of the floorbeams would tend to pull the top flanges of a through girder span toward the center of the track, resulting in a bending of the flanges, with the outside edge in compression and the inside edge in tension. A study of Tables 7, 8, and 9 will show that the top flanges of most of the girders were bending in toward the track but, based on the average of all the stresses shown for each span, the north girder of the 85-ft span, with an average bending of + 1.2 percent, the north girder of the 110-ft 2-in span, with + 1.1 percent, and the south girder of the 107-ft span, with + 6.3 percent, were bending away from the track. Simultaneous stresses recorded in the knee frames indicated that some of the girders were being pulled in toward the track center by a tensile stress in the frame while other knee frames were in compression.

10. Stress Distribution in Top Flange

Several gages were placed on the top flange of the south girder of the 55-ft deck span to study the distribution of the longitudinal stresses between the cover plates and flange angles and to determine the magnitude of the transverse stresses in the cover plate and flange angle fillets, as shown by the upper diagrams of Table 10. The 12 gages for this study were SR–4 wire gages and are indicated as G1 to G12, incl., as shown.

The stresses recorded at the center of the flange, gage G6, under the 3 locomotive classes at various speeds, are shown in Col. 5 of the table, while the simultaneous longitudinal stresses at the other gage positions, shown on Section AA, are tabulated in Cols. 6 to 14, incl., as a ratio of the stress at gage G6. For example, the 2-axle diesel crossing the span at 18.1 mph produced a compressive stress of 4.30 ksi in the flange at gage position G6, while the simultaneous stress at position G1 was only 0.40 of the stress at position G6. The stress on the inside of the flange at position G8 was 1.47 times the simultaneous stress recorded at position G6. Similar ratios are shown for the other gage locations, and it can be seen that the stress at position G8 varied from 1.30 to 1.56 times the stress recorded at position G6. The higher stresses recorded at position G8 are undoubtedly the result of the longitudinal compressive stress plus a compressive stress due to local bending of the flange when the tie deflects and bears on the inside edge of the flange. The data secured from these tests are shown schematically for a 2-axle diesel at 51.8 mph and a Class S2 steam locomotive at 51.9 mph by the lower diagrams on Table 10. It can be seen from these diagrams that the stresses on the flange angles are not as great as theory would predict, as they fall inside a line connecting the stress on the extreme fiber and the neutral axis.

The transverse stresses recorded in the cover plate and in the flange angle fillets under the 3 locomotive classes at various speeds are shown in Cols. 15, 16, and 17 of Table 10. It is evident from the transverse stresses in the cover plate, at gage position G7, that the tie deflection produced considerable local bending in the flange, as shown by the stresses in Col. 16. However, this bending of the flange does not have much influence on the fillet stresses as the fillets in most of the runs were in compression. Undoubtedly, this local bending of the flange had a marked effect on the web stresses just under the flange angle, but no readings were taken at this location.

11. Longitudinal Stress Distribution at End of Cover Plates

The stresses in the cover plates at several locations near the end of one top flange cover plate on the 107-ft and one on the 140-ft through plate-girder spans were determined from the SR–4 wire gages located as shown by the upper and center diagrams on Table 11. The stresses recorded in these cover plates under several diesel and steam locomotives are shown by the lower diagrams on Table 11, with each plotted value being the average of the 3 recorded stresses on each gage line. It can be seen that the stress near the end of the outside plate, gage line "C", is small for both girders, indicating that the first row of rivets was not developing the plate. A unit stress of 1.0 ksi in the 18 by $\frac{5}{8}$-in cover plate on the 107-ft span, as recorded under the Class S3 locomotive at 23.8 mph, means that the 2 end rivets were carrying a total load of 11.25 kips by a shearing stress of 9.35 ksi on the nominal diameter of the rivets.

The outside cover plate at these low stresses on the 107-ft span appears to be practically developed at gage line "d", as there was very little increase in the stresses at gage lines "e" and "f". However, by taking into account the increase in the bending moment and section modulus between gage lines "a" and "d", the stress at "d" should be about 88 percent of the stress at "a", or 5.45 ksi as compared with the recorded

stress of 4.50 ksi on this line. It is quite possible that the stresses on gage lines "a" and "b" were influenced locally by the cut-off of the cover plate. A unit stress of 4.30 ksi in the outside plate at gage line "d" on the 107-ft span, as recorded under the Class S3 locomotive at 11.3 mph, means that the 6 rivets between gage line "d" and the end of the cover plate were developing an average shearing stress of 13.40 ksi on the nominal diameter of the rivets. The outside cover plate on the 140-ft span does not appear to be developed much before gage line "c", but again taking into account the change in bending moment and section modulus, the plate appears to be developed at gage line "d" at these low stresses.

The calculated static stresses shown by the straight horizontal line at gage line "b" were adjusted to the recorded stress level through the use of the stress factors shown on Table 3. It is evident that the stresses at gage lines "a" and "b" on the 107-ft span were increased by the local effects produced by cutting off the cover plate.

12. Frequency of Maximum Stresses

The strain gage readings, as previously mentioned, were secured under regular trains with the speed reduced on only a few of the trains for slow-speed runs, so the stresses recorded during these tests actually indicate the frequency of occurrence of the maximum stresses on the various spans tested.

The maximum stresses recorded in 1 girder each of the 10 girder spans and the beams under one rail for the 35-ft beam span are shown on the left diagram of Figs. 103 to 113, incl. The maximum stresses recorded under the steam locomotives are shown by the solid circles while those under the diesel locomotives are shown by the open circles. These recorded maximum stress diagrams are a summation of all the stresses recorded in the flange near the center of the span under the individual locomotive classes, as shown on the diagrams of Figs. 80 to 90, incl.

The data shown in the tables of "Stress Range Distribution" on Figs. 103 to 113, incl., indicate the number of stresses at any one stress range which were recorded under each locomotive class for the particular span considered. For example, locomotives of the S3 class passed over the 35-ft beam span 25 times during the tests, but only 1 locomotive of this class produced stresses varying from 7 to 8 ksi, and only 11 locomotives produced stresses varying from 6 to 7 ksi, as shown in the upper right table of Fig. 103. Locomotives of the 2-axle diesel class passed over the span 26 times during the tests, but these locomotives did not produce stresses over 4 ksi. However, 8 of the 2-axle diesel locomotives produced stresses ranging from 3 to 4 ksi, while 18 produced stresses ranging from 2 to 3 ksi. Since a total of 89 locomotives passed over the span during the tests and only 1 produced stresses within the range of 7 to 8 ksi, it appears that only 1.6 percent of the trains passing over the span will produce the higher stresses for this particular distribution of power between the various locomotive classes. It can be seen from Figs. 103 to 113, incl., that the percentage of maximum stresses in the highest stress range varied from 1.0 percent in the 110-ft 2-in span (Fig. 112), to 14.1 percent in the 55-ft span (Fig. 107); however, values below 6.0 percent were found for all the spans except the 55-ft span.

The data tabulated in the "Stress Range Distribution" tables are shown graphically in the lower right diagrams of Figs. 103 to 113, incl.

13. Study of Strain Rosette Gages on Girder Webs

In order to show a comparison between the maximum recorded stresses on the girder webs found by a single gage at 45 deg and the principal stresses in the web,

strain rosette gages were used on 3 spans. The 40-ft and 55-ft eastbound spans and the 94-ft 10-in span had rosette gages positioned as shown on Table 15. The rosette gages used were of the rectangular, or 45-deg type, which consists of three 1-in SR–4 type AR–1 gages arranged as shown in the upper left diagrams of Table 15.

In cases of simple tension or compression (unidirectional unit stress) the stress at a point can be determined by multiplying the modulus of elasticity of the material E by the strain e observed on a single strain gages, that is, $S = E \times e$. In the case of biaxial stress, as would occur in a girder web, 3 strain observations must be made to establish the complete stress condition at the point in question. The reason for this is that the stress in one direction is not only effected by the strain in that direction but also by strains in other directions. Through experimentation there has been developed a constant μ, or Poisson's Ratio, which is the ratio of the unit lateral contraction to the unit axial elongation. Thus, by application of Poisson's Ratio, it has been found that the actual unit strain in any direction, e_x, is equal to the stress in that direction, S_y, divided by the modulus of elasticity, E, minus Poisson's Ratio, μ, times the stress at 90 deg, S_x, divided by E. That is, $e_y = \frac{S_y}{E} - \frac{S_x}{E}$.

However, the strain itself, read from the SR–4 gages, is not a true measurement ,because the gage is made up of a number of loops of wire and is sensitive to strain transverse to the axis of the gage. Each rosette gage comes shipped from the manufacturer marked with two factors. The first is a gage factor and is used to determine the strains read by the instrument (apparent strain). The second is an auxiliary factor which is used to convert apparent strain to true strain (see designation of symbols on Table 15). Although the transverse sensitivity is only about 3 percent of the axial sensitivity, the error in the principal stresses under certain conditions of stress may become greater than 3 percent. Therefore, the apparent strains, R_a, R_b, and R_c, were corrected by application of the 3 formulas involving the auxiliary factor 55 which were supplied by the rosette gage manufacturer and which are shown under designation of symbols on Table 15.

Normal principal stresses are defined as the normal stresses which occur on planes which have zero shear. The maximum number of principal stresses that can occur in a stressed body is three, but in the case of two-dimensional stress analysis, such as this study, there are just two. The greater of the two stresses is called the maximum principal normal stress S_{max} and the smaller the minimum principal stress S_{min}. These stresses are normal to planes which are at right angles to each other, as the sum of the normal stresses on perpendicular planes in a body is a constant. The two principal shearing stresses (q or maximum shearing stress) are numerically equal and act on planes which are perpendicular to each other, thus forming couples which are equal and opposite. The normal stress is not necessarily zero when the principal shearing stress occurs.

The conditions of strain at a point on a plane $\theta + 90$ deg from the x axis may be expressed by the following equations:

$$e_\theta = e_x \cos^2\theta + e_y \sin^2\theta + \gamma \frac{xy}{2} \sin 2\phi$$

$$\gamma_\theta = (e_y - e_x) \sin 2\phi + \gamma_{xy} \cos^2\theta$$

where $e\theta$ = the linear strain at a point in the direction θ from the X axis.

e_x, e_y = unit strains in the x and y directions.
γ_{xy} = unit shearing strain in the x and y directions.
$\gamma\theta$ = unit shearing strain on a plane $\theta + 90$ deg.

These equations describe a circle known as Mohr's Circle, with the ordinate representing $\frac{\gamma}{2}$ and the abscissa representing e. Positive or extension strains are plotted to the right and positive or clockwise shear couples are plotted down for the e axis. To determine the principal strains from Mohr's Circle the following method is used (see Table 14): Lay off $OF = e_a$, $OF'' = e_b$, and $OF' = e_c$. The center of Mohr's Circle is located halfway between F and F'. Lay off $FD = CF''$. CD is now the radius of the circle. The principal strains and their directions can now be taken from the circle. S_{max} and q may be determined by referring to the formulas on Table 15. S_{min} is calculated the same way as S_{max}, except that e_{max} and e_{min} are reversed in the formula.

The value obtained for the recorded maximum stress using only the "b" gage (45 deg) of the strain rosette has been included under the symbol R_bE. This value is the apparent strain as read from the instrument, R_b,times the modulus, E, and is representative of the readings obtained from the 45-deg gages used in the preceding girder web results discussed under Maximum Stresses and Total Impacts. It can be seen that in the cases shown on Table 15, R_bE was greater than the maximum principal normal stress (S_{max}) for all rosettes located at midheight on the girder web, and less than S_{max} for the rosettes located at the top of the girder web. It can also be seen that the angle at which the principal stresses act was about 132 deg for the rosettes located at midheight and 138 deg for the rosette at the top of the web.

A comparison of the magnitude of the maximum principal stress, S_{max}, and the maximum recorded stress from the 45-deg gage, R_bE, at midheight on the web, indicates that the 45-deg gage readings varied from 6.8 to 23.5 percent greater than the maximum principal stress, with an average variation of 15 percent greater for the 6 readings compared on Table 15.

It should be pointed out that the data for this study were obtained from rosette gages located on one side of the web only. Thus, an average value to correct out any bending stress in the web plates due to vibration was not possible.

H. CONCLUSIONS

The tests on these 11 spans afforded an opportunity to measure and analyze the static and dynamic effects of both diesel and steam locomotive loadings at various speeds on both deck and through girder spans of different lengths. The conclusions stated in this report must be considered as applying to these spans only; the final conclusions on girder spans will not be written until the present series of tests is completed.

From the data as found from these tests it seems logical to conclude that:

1. Static Stresses

The recorded static live load stresses in the girder flanges averaged 15 percent lower than the calculated stresses, with the results for individual spans varying from 4 percent higher to 26 percent lower.

The web shear at the end and quarter point was found to vary in the same manner, except that the recorded static web shear at the end of one 40-ft span was 42 percent below the calculated stress.

The stringers and center floorbeams for the 3 spans where these were tested showed similar results, but the 1 end floorbeam tested was found to have only half the calculated static stress.

2. Speed Effects

The speed effects under the diesel locomotives were about the same as under the steam locomotives and were generally less than 10 percent of the static stresses, but some were higher and one was 63 percent of the recorded static stress.

3. Roll Effects

The roll effects were generally within the AREA design specification allowance and were about the same in magnitude under the diesel and steam locomotives. There was no apparent relation between the magnitude of the roll effect and the speed of the locomotives.

4. Track Effects—Diesel Locomotives

The track effects under the diesel locomotives were generally less than 20 percent of the measured static stresses, with one value as high as 36 percent. The track effects generally increased with an increase in speed.

5. Track and Hammer-Blow Effects—Steam Locomotives

The track and hammer-blow effects under the steam locomotives were somewhat higher than the track effects under diesel locomotives. They generally increased with an increase in speed, except that for the longer spans, where sychronous speeds were attained, there was usually a reduction at higher speeds.

6. Total Impacts—Diesel Locomotives

The total impacts under the diesel locomotives frequently exceeded the impacts under steam locomotives. The total impacts in the flanges of 3 spans and in the web plates of 5 spans exceeded the AREA design allowance.

7. Total Impacts—Steam Locomotives

The total impacts under the steam locomotives exceeded the AREA design allowance for the flanges of 3 spans and the web plates of 4 spans.

8 Maximum Stresses

The maximum recorded stresses under both diesel and steam locomotives were generally well below the calculated stresses, using the current AREA design impact allowances. The Class L2–b steam locomotives on the 110-ft span produced stresses in the flanges which were somewhat higher than the calculated maximum.

The recorded maximum stresses in the web plates near the ends of the spans were below the calculated maximum stresses with the exception of 2 runs on the longer spans where they were slightly above.

The recorded maximum stresses in the web plates near the quarter points of the spans exceeded the calculated maximums in some cases.

9. Lateral and Cross-Frame Bracing

The maximum direct stresses in the cross frames and lateral bracing ranged from tension to compression during the passage of trains. These stresses were generally higher under steam locomotives than under diesel locomotives, and increased with an increase in speed.

The highest average stress recorded was about 7.2 ksi and the highest range was from 4.9 ksi tension to 6.6 ksi compression. Considerable bending existed in the bracing members, especially in angles connected through only one leg.

The maximum recorded stresses were well below the AREA calculated design stresses for the top laterals, but many recorded stresses in the bottom laterals exceeded the calculated values and corresponding lateral loads as high as 37.8 kips were found.

10. Frequency of Maximum Stresses

Only a small percentage of the trains passing over a bridge produced stresses near the maximum.

11. Comparison of Top and Bottom Flange Stresses

The stresses in the top flanges of the girders varied from 5 percent lower than the bottom flange stress in a deck girder span to 13 percent higher in a through girder span, except for the south girder of the 85-ft span where the top flange stress was 33 percent higher than the bottom flange stress.

12. Distribution of Stress in Girder Flanges

The flange angles were carrying a smaller portion of the flange stress than theory would predict for the one girder where this distribution was studied.

A transverse bending stress of 8.6 ksi in the cover plate due to ties bearing on the inside of the flange was found in one girder.

In most cases there was little transverse bending in the girder flanges, although one measurement for the 55-ft span showed 56 percent higher stress on one edge of the cover plate than the average.

13. Stresses at Ends of Cover Plates

For the low stresses in these tests, the cover plates were carrying their full share of the stress at a point about 9 in from the end of the plate.

The inside cover plate appeared to be carrying more than its share of stress just outside the end of the next cover plate.

14. Strain Rosette Gages on Girder Webs

A study of web stresses on 3 spans by strain rosette gages indicated that the web stresses measured by single SR–4 gages at 45 deg on the web plate near the ends of the girders were about 15 percent higher than the actual maximum principal stresses due to the effect of Poisson's Ratio.

TABLE 1

C.M.ST.P.&P. R.R. BRIDGE TESTS

RATING OF TEST LOCOMOTIVES

LOCOMOTIVE TYPE & CLASS / SPAN TYPE FLOOR	2-AXLE DIESEL	3-AXLE DIESEL	ATLANTIC 4-4-2 "A"	MIKADO 2-8-2 "L-2B"	NORTHERN 4-8-4	
					"S2"	"S3"
35'-0 WF BEAM BALLASTED TIMBER	E 36.2 (3 UNITS 89A,89B,89C)	E 38.8 (1 UNIT 11B)		E 52.6		E 56.4
40'-0 D.P.G. OPEN TIMBER	E 40.1 (3 UNITS 90A,90B,90C)	E 38.2 (2 UNITS 16,17)			E 63.8	E 57.7
46'-8 3/4 D.P.G BALLASTED TIMBER			E 42.6	E 51.9	E 64.3	E 59.7
55'-0 D.P.G. OPEN TIMBER	E 40.9 (3 UNITS 90A,90B,90C)	E 40.5 (2 UNITS 16,17)			E 67.8	E 61.8
85'-0 T.P.G. BALLASTED TIMBER	E 35.7 (3 UNITS 89A,89B,89C)	E 34.9 (1 UNIT 11B)		E 46.8		E 61.4
94'-10 D.P.G. OPEN TIMBER	E 36.0 (3 UNITS 69A,69B,69C)	E 40.2 (2 UNITS 5A,6A)			E 65.0	E 61.5
107'-0 T.P.G. BALLASTED TIMBER	E 36.4 (3 UNITS 49A,49B,49C)	E 32.9 (1 UNIT 18)			E 65.5	E 60.7
110'-2 T.P.G. BALLASTED TIMBER			E 48.3	E 42.0	E 65.0	E 60.7
140'-0 T.P.G. OPEN TIMBER	E 36.7 (3 UNITS 71A,71B,71C)			E 42.3	E 62.8	E 58.4

TABLE 2

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
BENDING MOMENT AT CENTER OF SPAN

SPAN & TYPE OF FLOOR	TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
	CLASS	NUMBER	NORTH GIRDER	SOUTH GIRDER	AVERAGE			
COLUMN 1	2	3	4	5	6	7	8	9
35'-0 WF BEAM BALLASTED TIMBER	2-AXLE DIESEL		3.07	2.82	2.95	3.28	0.90	0.93
			3.08	3.05	3.07		0.94	
			2.98	3.05	3.02		0.92	
			2.93	3.00	2.97		0.90	
	3-AXLE DIESEL		3.20	3.28	3.24	3.51	0.92	
			3.55	3.26	3.41		0.97	
			3.29	3.10	3.20		0.91	
			3.41	3.26	3.34		0.95	
	L2b	452	4.08	3.95	4.02	4.76	0.84	0.99
		424	4.49	4.40	4.45		0.93	
		450	4.58	4.00	4.29		0.90	
	S3	265	6.12	5.41	5.77	5.10	1.13	
			5.50	4.77	5.14		1.01	
			5.37	4.64	5.01		0.98	
			5.59	5.37	5.48		1.07	
			5.77	5.18	5.48		1.07	
40'-0 D.P.G. WESTBOUND OPEN TIMBER	2-AXLE DIESEL		2.72	2.85	2.78	4.08	0.68	0.72
			2.53	2.53	2.53		0.62	
			2.81	3.16	2.98		0.73	
	3-AXLE DIESEL		2.90	2.74	2.82	3.88	0.73	
			3.09	3.05	3.07		0.79	
			3.18	2.85	3.01		0.78	
	S2	206	4.31	4.42	4.36	6.48	0.67	0.76
		201	5.15	5.47	5.31		0.82	
		232	4.49	4.11	4.30		0.66	
		215	5.53	6.00	5.76		0.89	
40'-0 D.P.G. EASTBOUND OPEN TIMBER	2-AXLE DIESEL		3.14	2.97	3.05	4.08	0.75	0.80
			2.47	2.50	2.49		0.61	
	3-AXLE DIESEL		3.80	3.36	3.58	3.88	0.92	
			3.70	3.36	3.53		0.91	
	S2	228	4.27	5.28	4.77	6.48	0.74	0.77
		214	4.57	5.66	5.11		0.79	
46'-8¾ D.P.G. BALLASTED TIMBER	A		4.39	4.90	4.65	5.27	0.88	0.85
	S2	206	6.78	7.06	6.92	8.00	0.87	
	S3	266	5.72	6.20	5.96	7.42	0.81	
55'-0 D.P.G. WESTBOUND OPEN TIMBER	2-AXLE DIESEL		3.33	3.09	3.21	4.31	0.74	0.76
			3.07	2.88	2.98		0.69	
			3.33	3.18	3.25		0.75	
	3-AXLE DIESEL		3.59	3.09	3.34	4.28	0.78	
			3.84	3.18	3.51		0.82	
	S2	206	5.31	5.34	5.33	7.15	0.74	0.83
		201	6.06	5.98	6.02		0.84	
		232	6.15	5.11	5.63		0.79	
		215	7.09	6.40	6.75		0.95	
55'-0 D.P.G. EASTBOUND OPEN TIMBER	2-AXLE DIESEL		2.82	3.11	2.97	4.31	0.69	0.76
			2.74	3.02	2.88		0.67	
	3-AXLE DIESEL		3.80	3.82	3.81	4.28	0.89	
			3.09	3.64	3.36		0.79	
	S2	228	5.56	5.78	5.67	7.15	0.79	0.83
		214	5.92	6.40	6.16		0.86	

NOTE : ALL STRESSES SHOWN ARE TENSION AND IN KSI.

TABLE 3

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES BENDING MOMENT AT CENTER OF SPAN

SPAN & TYPE OF FLOOR	TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
	CLASS	NUMBER	NORTH GIRDER	SOUTH GIRDER	AVERAGE			
COLUMN 1	2	3	4	5	6	7	8	9
85'-0 T.P.G. BALLASTED TIMBER	2-AXLE DIESEL		2.96	3.04	3.00	3.94	0.76	0.74
			2.96	2.77	2.87		0.73	
			3.14	3.04	3.09		0.78	
			3.06	2.96	3.01		0.76	
	3-AXLE DIESEL		2.83	2.68	2.78	3.84	0.77	
			2.70	2.68	2.69		0.70	
	L2b	452	3.68	3.60	3.64	5.16	0.70	0.75
		424	3.86	3.69	3.77		0.73	
		450	4.04	3.97	4.00		0.77	
		452	4.04	3.74	3.89		0.75	
	S3	265	5.21	4.80	5.00	6.77	0.74	
			5.21	4.71	4.96		0.73	
			5.48	4.99	5.23		0.77	
			5.56	5.08	5.32		0.79	
94'-10 D.P.G. OPEN TIMBER	2-AXLE DIESEL		3.57	3.30	3.44	3.80	0.90	0.98
	3-AXLE DIESEL		4.49	4.54	4.51	4.26	1.06	
	S2	235	5.59	5.58	5.59	6.88	0.81	0.88
			6.52	6.33	6.42		0.93	
			6.52	6.33	6.42		0.93	
			6.05	5.85	5.95		0.86	
107'-0 T.P.G. BALLASTED TIMBER	2-AXLE DIESEL		3.81	3.32	3.57	3.82	0.93	0.88
			3.56	3.32	3.44		0.90	
	3-AXLE DIESEL		3.20	2.58	2.89	3.46	0.83	
	S2	208	5.79	5.18	5.48	6.86	0.80	0.85
		240	6.27	5.66	5.96		0.87	
			6.27	5.42	5.85		0.85	
		208	5.90	5.41	5.66		0.82	
	S3	264	5.67	5.18	5.43	6.38	0.85	
			5.79	5.42	5.61		0.87	
			5.42	5.18	5.30		0.83	
			5.91	5.42	5.67		0.89	
110'-2 T.P.G. BALLASTED TIMBER	A	3	-5.50	-4.90	-5.20	-4.92	1.06	1.04
	S2	206	-7.05	-6.53	-6.79	-6.61	1.03	
	S3	266	-6.49	-6.06	-6.27	-6.18	1.02	
140'-0 T.P.G. OPEN TIMBER	2-AXLE DIESEL		3.36	3.58	3.47	3.83	0.90	0.90
			3.36	3.23	3.29		0.86	
			3.47	3.34	3.40		0.89	
			3.68	3.46	3.57		0.93	
	L2b	429	3.26	3.34	3.30	4.41	0.75	0.81
	S2	222	5.31	5.30	5.31	6.57	0.81	
		218	5.74	5.54	5.64		0.86	
		222	5.41	5.52	5.46		0.83	
		218	5.20	5.06	5.13		0.78	
	S3	268	5.20	5.19	5.20	6.11	0.85	

NOTE: ALL STRESSES SHOWN ARE TENSILE EXCEPT WHERE NOTED.
ALL STRESSES SHOWN ARE IN KSI.

TABLE 4

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES

WEB SHEAR AT END OF GIRDER

SPAN & TYPE OF FLOOR	TEST LOCOMOTIVE		RECORDED STATIC STRESS			AVERAGE CALCULATED STATIC STRESS *	STRESS FACTOR = RECORDED / CALCULATED	
	CLASS	NUMBER	NORTH GIRDER	SOUTH GIRDER	AVERAGE			
COLUMN 1	2	3	4	5	6	7	8	9
40'-0 D.P.G. WESTBOUND OPEN TIMBER	2-AXLE DIESEL		1.87	2.14	2.01	3.56	0.56	0.58
			2.13	2.07	2.10		0.59	
	3-AXLE DIESEL		1.87	1.80	1.84	3.43	0.54	
			2.36	2.08	2.22		0.65	
			2.16	1.58	1.87		0.55	
	S2	201	3.48	3.56	3.52	5.24	0.67	0.74
		215	4.29	4.19	4.24		0.81	
40'-0 D.P.G. EASTBOUND OPEN TIMBER	3-AXLE DIESEL		2.79	2.61	2.70	3.43	0.79	0.78
			2.69	2.52	2.61		0.76	
	S2	228	3.97	3.85	3.91	5.25	0.75	0.75
46'-8¾ D.P.G. OPEN TIMBER	A	3		3.42		3.64	0.94	0.88
	S2	206		4.36		5.48	0.80	
	S3	266		4.23		4.75	0.89	
55'-0 D.P.G. WESTBOUND OPEN TIMBER	2-AXLE DIESEL		2.76	2.76	2.76	3.54	0.78	0.81
			2.34	2.67	2.51		0.71	
	3-AXLE DIESEL		2.28	3.13	2.71	3.59	0.76	
			3.23	3.36	3.30		0.92	
			3.24	3.04	3.14		0.87	
	S2	206	4.14	4.26	4.20	5.20	0.81	0.85
		201	4.72	5.01	4.87		0.94	
		232	4.18	4.12	4.15		0.80	
55'-0 D.P.G. EASTBOUND OPEN TIMBER	3-AXLE DIESEL		3.29	3.38	3.34	3.59	0.93	0.90
			3.20	2.96	3.08		0.86	
	S2	228	4.61	3.84	4.23	5.20	0.81	0.87
		214	5.15	4.53	4.84		0.93	
85'-0 T.P.G. BALLASTED TIMBER	2-AXLE DIESEL		2.60			3.13	0.83	0.79
			2.32				0.74	
			2.28				0.73	
	3-AXLE DIESEL		2.91			3.02	0.96	
			2.23				0.74	
			2.18				0.72	
	L2-8	452	2.81			4.05	0.69	0.74
		424	2.77				0.68	
		450	3.07				0.76	
	S3	265	3.75			4.87	0.77	
			3.57				0.73	
			4.06				0.83	
94'-10 D.P.G. BALLASTED TIMBER	3-AXLE DIESEL		2.32	2.52	2.42	2.45	0.99	0.99
	S2	235	3.08	3.10	3.09	3.86	0.80	0.85
			3.50	3.34	3.42		0.89	
			3.50	3.20	3.35		0.87	
107'-0 T.P.G. BALLASTED TIMBER	S2	240	3.43	3.66	3.55	4.58	0.78	0.81
			3.43	3.72	3.58		0.78	
	S3	264	3.37	4.33	3.85	4.19	0.92	
			3.37	3.60	3.49		0.83	
			3.01	3.25	3.13		0.75	
110'-2 T.P.G. BALLASTED TIMBER	A	3		3.27		3.30	0.99	0.94
	L2-B	462		3.12		3.13	1.00	
	S2	206		4.35		4.62	0.94	
	S3	266		3.45		4.24	0.81	
140'-0 T.P.G. OPEN TIMBER	S2	222	3.11	3.02	3.07	3.57	0.86	0.86
			3.16	3.13	3.15		0.88	
			2.94	2.97	2.96		0.83	

NOTE: ALL STRESSES SHOWN ARE TENSION AND IN KSI.

* CALCULATED STATIC STRESSES COMPUTED USING THE FOLLOWING FORMULA:

$$f_{w_{(45°)}} = \tfrac{1}{2} fs + v, \text{ WHERE } v = \frac{VQ}{Ib}$$

TABLE 5

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES

SPAN LENGTH & FLOOR TYPE	TEST LOCOMOTIVE CLASS	TEST LOCOMOTIVE NUMBER	WEB SHEAR AT QUARTER POINT OF SPAN * RECORDED STATIC STRESS NORTH GIRDER	WEB SHEAR AT QUARTER POINT OF SPAN * RECORDED STATIC STRESS SOUTH GIRDER	WEB SHEAR AT QUARTER POINT OF SPAN * RECORDED STATIC STRESS AVERAGE	WEB SHEAR AT QUARTER POINT OF SPAN * AVE. CALCULATED STATIC STRESS	WEB SHEAR AT QUARTER POINT OF SPAN * STRESS FACTOR RECORDED/CALCULATED		BENDING MOMENT AT ℄ STRINGERS RECORDED STATIC STRESS NORTH STRINGER	BENDING MOMENT AT ℄ STRINGERS RECORDED STATIC STRESS SOUTH STRINGER	BENDING MOMENT AT ℄ STRINGERS RECORDED STATIC STRESS AVERAGE	BENDING MOMENT AT ℄ STRINGERS AVE. CALCULATED STATIC STRESS	BENDING MOMENT AT ℄ STRINGERS STRESS FACTOR RECORDED/CALCULATED		BENDING MOMENT IN CENTER FLOORBEAMS RECORDED STATIC STRESS AT ℄ NORTH STRINGER	BENDING MOMENT IN CENTER FLOORBEAMS RECORDED STATIC STRESS AT ℄ SOUTH STRINGER	BENDING MOMENT IN CENTER FLOORBEAMS RECORDED STATIC STRESS AVE AT ℄ FLOORBEAM	BENDING MOMENT IN CENTER FLOORBEAMS AVE. CALCULATED STATIC STRESS	BENDING MOMENT IN CENTER FLOORBEAMS STRESS FACTOR RECORDED/CALCULATED		BENDING MOMENT IN END FLOORBEAMS RECORDED AT ℄ FLOORBEAM	BENDING MOMENT IN END FLOORBEAMS AVE. CALCULATED STATIC STRESS	BENDING MOMENT IN END FLOORBEAMS STRESS FACTOR RECORDED/CALCULATED	
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
107'-0 T.P.G. BALLASTED TIMBER	2 AX. DIESEL		1.20	1.20	1.20	1.50	0.80	0.81	3.46	3.19	3.32	4.59	0.72	0.80	2.86	2.65	2.75	3.08	0.89	0.86				
			0.90	1.10	1.00		0.67		3.00	3.32	3.16		0.69		2.62	2.65	2.63		0.85					
	3 AX. DIESEL		1.30	1.40	1.35	1.40	0.96		3.58	4.14	3.86	3.85	1.00		3.09	3.20	3.14	3.70	0.85					
	S2	208	2.00	2.00	2.00	2.45	0.82	0.87				5.13		1.03				5.20		0.93				
		208	1.80	2.00	1.90		0.77		4.85	5.09	4.97		0.97		4.76	4.75	4.76		0.92					
		240							5.07	4.73	4.90		0.95		4.76	4.52	4.64		0.89					
		240							5.89	4.85	5.37		1.05		5.00	4.52	4.76		0.92					
	S3	264		2.20		2.30	0.96		5.07	4.85	4.96	4.58	1.08		4.76	4.41	4.58	4.72	0.97					
				1.90			0.83		5.89	4.02	4.95		1.08		4.65	4.52	4.58		0.97					
				2.10			0.91		4.73	4.61	4.67		1.02		4.65	4.19	4.42		0.94					
				2.10			0.91																	
110'-2 T.P.G. BALLASTED TIMBER	A	3							4.22	3.92	4.07	4.37	0.93				4.07	4.35	0.94		2.56	4.36	0.59	
	S2	206							6.57	6.25	6.41	5.48	1.17	1.02			5.70	6.24	0.91	0.88	2.56	5.07	0.51	0.52
	S3	266							5.40	4.65	5.03	5.30	0.95				4.48	5.69	0.79		2.10	4.61	0.46	
140'-0 T.P.G. OPEN TIMBER	2 AX. DIESEL		1.10	0.90	1.00	1.27	0.79	0.79	3.45	3.31	3.38	4.50	0.75	0.73	2.90	2.95	2.92	3.73	0.78	0.76				
									3.03	2.81	2.92		0.65		2.79	2.70	2.74		0.73					
									3.78	3.21	3.49		0.78		3.01	2.83	2.92		0.78					
	L2B	429							4.97	4.92	4.94	5.34	0.92		4.72	4.55	4.63	5.47	0.85					
	S2	222							5.62	5.81	5.72		1.05		6.34	5.78	6.06		0.95					
		218							5.73	5.33	5.53	5.45	1.03		5.80	5.54	5.67	6.36	0.89					
		222							5.84	6.02	5.93		1.09	1.01	6.34	6.27	6.30		0.99	0.92				
	S3	268	1.50	1.50	1.50	2.01	0.75	0.81																
			1.80	1.70	1.75		0.87		4.11	5.01	4.56	4.84	0.94		5.48	5.16	5.32	5.76	0.92					
			1.70	1.60	1.65		0.82																	

* CALCULATED STATIC STRESSES COMPUTED USING THE FOLLOWING FORMULA: $f_{w(45°)} = \frac{1}{2} f_s + v$, WHERE $v = \frac{VQ}{Ib}$

TABLE 6

COMPARISON OF TOP AND BOTTOM FLANGE RECORDED STRESSES

SPAN LENGTH & FLOOR TYPE	TEST LOCOMOTIVE			NORTH GIRDER				SOUTH GIRDER			
	CLASS	NUMBER	SPEED MPH	TOP FLANGE	BOTTOM FLANGE	VARIATION FROM BOTTOM FLANGE		TOP FLANGE	BOTTOM FLANGE	VARIATION FROM BOTTOM FLANGE	
						STRESS	PERCENT			STRESS	PERCENT
COL. 1	2	3	4	5	6	7	8	9	10	11	12
85'-0 T.P.G. BALLASTED TIMBER	2-AXLE DIESEL		57.2	-3.37	+3.23	+0.14	+ 4.3	- 3.83	+3.32	+0.51	+ 15.4
			57.8	-3.66	+3.05	+0.61	+20.0	- 4.03	+2.86	+ 1.17	+ 40.9
			57.8	-3.66	+3.05	+0.61	+20.0	- 3.93	+2.86	+ 1.07	+ 37.4
	3-AXLE DIESEL		74.0	-3.19	+2.70	+0.49	+ 18.2	- 3.53	+2.77	+0.76	+ 27.5
			80.9	-4.40	+3.77	+0.63	+ 16.7	- 4.61	+3.41	+ 1.20	+ 35.2
			85.5	-3.47	+3.32	+0.15	+ 4.5	- 3.83	+3.23	+0.60	+ 18.6
	L2b	431	37.5	-5.35	+4.84	+0.51	+ 10.6	- 6.39	+4.61	+ 1.78	+ 38.6
		450	40.5	-6.01	+5.29	+0.72	+ 13.6	- 6.78	+4.70	+2.08	+ 44.2
			43.2	-5.73	+5.03	+0.70	+ 13.9	- 6.78	+4.89	+ 1.89	+ 38.6
	S3	265	69.1	-6.48	+5.74	+0.74	+ 12.9	- 7.76	+5.72	+2.04	+ 35.6
			71.7	-6.10	+5.74	+0.36	+ 6.3	- 7.07	+5.62	+ 1.45	+ 25.8
			74.0	-6.84	+5.92	+0.92	+ 15.5	- 7.66	+5.62	+2.04	36.3
94'-10 D.P.G. OPEN TIMBER	2-AXLE DIESEL		55.2	-3.68	+4.04	-0.36	- 8.9	- 3.77	+3.78	-0.01	- 0.3
			56.2	-3.77	+3.48	+0.29	+ 8.3	- 3.58	+3.78	- 0.20	- 5.3
			57.8	-4.21	+4.04	+0.17	+ 4.2	- 4.59	+4.53	+0.06	+ 1.3
	3-AXLE DIESEL		84.1	-4.13	+3.94	+0.19	+ 4.8	- 3.95	+3.97	-0.02	- 0.5
			84.8	-4.13	+4.03	+0.10	+ 2.5	- 3.95	+4.34	- 0.39	- 9.0
			84.9	-4.39	+4.58	- 0.19	- 4.1	- 4.40	+4.62	- 0.22	- 4.8
	S2	235	50.3	-6.28	+6.64	- 0.36	- 5.4	- 5.97	+6.62	- 0.65	- 9.8
			57.3	-6.00	+6.79	- 0.79	- 11.6	- 5.97	+6.42	- 0.45	- 7.0
			65.1	-6.00	+6.88	- 0.88	- 12.8	- 5.79	+6.42	- 0.63	- 9.8
	S3	265	27.3	-6.46	+6.14	+0.32	+ 5.2	- 6.34	+6.33	+0.01	+ 0.2
		260	36.6	-6.10	+7.15	- 1.05	- 14.7	- 5.69	+6.89	- 1.20	- 17.4
		265	51.4	-6.46	+6.33	+0.13	+ 2.1	- 6.34	+6.42	- 0.08	- 1.2
107'-0 T.P.G. BALLASTED TIMBER	2-AXLE DIESEL		57.2	-3.72	+3.70	+0.02	+ 0.5	- 3.87	+3.70	+0.17	+ 4.6
			60.6	-3.60	+3.45	+0.15	+ 4.4	- 3.63	+3.70	- 0.07	+ 1.9
			61.2	-3.48	+3.45	+0.03	+ 0.9	- 3.63	+3.33	+0.30	+ 9.0
	3-AXLE DIESEL		89.8	-3.72	+3.94	- 0.22	- 5.6	- 3.15	+2.58	+0.57	+22.1
			90.9	-3.72	+3.58	+0.14	+ 3.9	- 3.15	+2.46	+0.69	+28.0
			91.0	-3.72	+3.82	-0.10	- 2.6	- 2.91	+2.71	+0.20	+ 7.4
	S2	208	45.8	-6.21	+6.04	+0.17	+ 2.8	- 6.66	+6.16	+0.50	+ 8.1
		206	51.7	-5.81	+6.03	- 0.22	- 3.6	- 6.30	+6.28	+0.02	+ 0.3
		216	51.7	-5.96	+6.41	- 0.45	- 7.0	- 5.82	+5.92	-0.10	- 1.7
	S3	264	55.8	-5.70	+5.66	+0.04	+ 0.7	- 6.66	+6.16	+0.50	+ 8.1
			59.6	-5.70	+5.55	+0.15	+ 2.7	- 6.06	+5.66	+0.40	+ 7.1
			67.0	-6.21	+5.92	+0.29	+ 4.9	- 6.78	+6.28	+0.50	+ 8.0
140'-0 T.P.G. OPEN TIMBER	2-AXLE DIESEL		58.1	-3.58	+3.89	- 0.31	- 8.0	- 3.44	+3.58	-0.14	- 3.9
			59.3	-3.58	+3.36	+0.22	+ 6.5	- 3.22	+3.58	-0.36	- 10.1
			60.0	-3.46	+2.71	+0.75	+27.7	- 3.33	+3.23	+0.10	+ 3.1
	L2b	424	40.7	-4.15	+3.79	+0.36	+ 9.5	- 4.18	+4.15	+0.03	+ 0.7
		468	43.1	-4.38	+3.79	+0.59	+ 15.6	- 4.18	+3.80	+0.38	+ 10.0
		447	46.4	-4.15	+3.69	+0.46	+ 12.5	- 3.65	+3.69	-0.04	- 1.1
	S2	222	60.9	-6.46	+5.42	+1.04	+19.2	- 6.54	+5.88	+0.66	+ 11.2
			61.7	-6.22	+5.53	+0.69	+ 12.5	- 6.65	+5.77	+0.88	+ 15.2
			62.0	-6.22	+5.42	+0.80	+ 14.8	- 6.44	+5.88	+0.56	+ 9.5
	S3	268	47.8	-5.76	+5.42	+0.34	+ 6.3	- 5.15	+5.19	-0.04	- 0.8
		266	49.8	-6.22	+5.96	+0.26	+ 4.4	- 6.22	+5.99	+0.23	+ 3.8
		260	51.7	-6.11	+5.42	+0.69	+ 12.7	- 5.90	+5.54	+0.36	+ 6.5

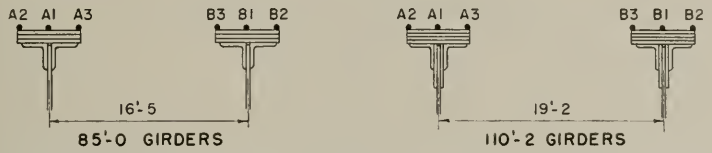
NOTE: STRESSES SHOWN ARE IN KSI

COL. 5, 6, 9 & 10. THE STRESSES RECORDED AT THE GAGE POSITION HAVE BEEN CORRECTED TO SHOW THE STRESSES AT THE EXTREME FIBER.

COL. 7, 8, 11 & 12. A POSITIVE SIGN IN THESE COLUMNS MEANS THAT THE TOP FLANGE STRESS IS GREATER THAN THE BOTTOM FLANGE STRESS BY THE AMOUNT SHOWN.

TABLE 7

VARIATION OF RECORDED STRESSES ACROSS TOP FLANGE



SPAN	TEST LOCOMOTIVE			NORTH GIRDER						SOUTH GIRDER					
	CLASS	NUMBER	SPEED MPH	GAGES			AVER A2 &A3	VARIATION FROM AVER.		GAGES			AVER. B2 &B3	VARIATION FROM AVER.	
				A1	A2	A3		STRESS	%	B1	B2	B3		STRESS	%
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
85'-0 T.P. GIRDER	2 AXLE DIESEL	75	48.4	2.91	3.16	3.57	3.37	+0.20	+ 5.9	3.34	3.49	2.79	3.14	-0.35	- 11.1
			57.2	3.37	3.69	4.13	3.91	+0.22	+ 5.6	3.83	3.77	3.35	3.56	-0.21	- 5.9
	3 AXLE DIESEL	18	17.9	2.90	3.16	3.57	3.37	+0.20	+ 5.9	3.34	3.49	2.79	3.14	-0.35	- 11.1
		18	75.5	3.47	3.69	3.95	3.82	+0.13	+ 3.4	3.73	3.86	3.25	3.56	-0.31	- 8.7
	L2B	468	21.0	4.70	4.74	5.55	5.15	+0.40	+ 7.8	5.59	5.34	4.65	5.00	-0.35	- 7.0
		439	27.2	4.88	5.45	5.55	5.50	+0.05	+ 0.9	5.50	5.61	4.93	5.27	-0.34	- 6.5
		450	27.6	3.94	4.92	5.84	5.38	+0.46	+ 8.6	5.69	5.88	4.65	5.27	-0.62	- 11.8
	S3	265	3.9	6.10	6.75	6.57	6.66	-0.09	- 1.4	6.97	6.35	5.86	6.11	-0.25	- 4.1
			4.5	6.38	6.94	6.86	6.90	-0.04	- 0.6	7.17	6.62	6.14	6.38	-0.24	- 3.8
			4.5	5.82	6.32	6.30	6.31	-0.01	- 0.2	6.59	6.16	5.67	5.94	-0.27	- 4.6
			5.0	5.92	6.68	6.40	6.54	-0.14	- 2.1	6.87	6.07	5.78	5.93	-0.15	- 2.5
			5.6	6.00	5.70	6.40	6.05	+0.35	+ 5.8	6.87	6.25	6.05	6.15	-0.10	- 1.6
			6.6	6.19	6.59	6.77	6.68	+0.09	+ 1.3	6.97	6.53	5.86	6.20	-0.34	- 5.5
			15.2	6.10	6.68	6.58	6.63	-0.05	- 0.8	6.97	6.62	5.95	6.29	-0.34	- 5.4
			19.3	6.38	6.84	7.05	6.95	+0.10	+ 1.4	6.97	6.45	6.33	6.39	-0.06	- 0.9
			29.2	6.38	7.29	6.86	7.08	-0.22	- 3.1	6.97	6.53	5.95	6.24	-0.39	- 6.3
			34.1	6.19	7.02	6.30	6.66	-0.36	- 5.4	7.27	6.71	6.51	6.61	-0.10	- 1.5
			35.2	6.47	6.93	7.14	7.04	+0.10	+ 1.4	7.27	6.89	5.95	6.42	-0.47	- 7.3
			38.0	6.38	7.20	6.68	6.94	-0.26	- 3.7	7.27	6.53	6.52	6.53	-0.01	- 0.2
			38.8	6.47	7.20	6.96	7.08	-0.12	- 1.7	7.37	7.17	6.42	6.80	-0.38	- 5.6
			39.3	6.56	7.46	7.33	7.40	-0.07	- 0.9	7.66	7.17	6.42	6.80	-0.38	- 5.6
			53.4	6.38	7.20	7.05	7.13	-0.08	- 1.1	7.18	6.71	6.23	6.57	-0.34	- 5.2
			71.7	6.10	6.14	7.04	6.59	+0.45	+ 6.8	7.07	7.35	5.40	6.38	-0.98	- 15.4
			74.0	6.84	7.81	7.05	7.43	-0.38	- 5.1	7.16	6.80	7.25	7.03	+0.22	+ 3.1
110'-2 T.P. GIRDER	A	4	44.8	5.83	5.91	6.01	5.96	+0.05	+ 0.8	5.93	5.89	6.36	6.13	+0.23	+ 3.7
		6	86.0	5.60	6.64	6.33	6.49	-0.16	- 2.5	5.51	6.78	6.13	6.46	-0.33	- 5.1
		7	86.0	5.84	6.76	7.33	7.05	+0.28	+ 4.0	5.79	7.36	6.36	6.86	-0.50	- 7.3
		1	90.0	6.18	6.38	7.00	6.69	+0.31	+ 4.6	6.49	7.36	7.20	7.28	-0.08	- 1.1
		3	90.0	4.90	6.03	6.00	6.00	-0.02	- 0.3	4.94	6.63	5.54	6.09	-0.55	- 9.0
	L2B	473	29.1	5.84	6.75	6.50	6.63	-0.13	- 2.0	5.93	7.20	5.78	6.49	-0.71	-10.9
		480	39.0	6.08	7.23	6.50	6.87	-0.37	- 5.4	6.08	7.36	5.89	6.63	-0.74	-11.2
	S2	212	24.3	7.71	6.75	6.84	6.80	+0.04	+ 0.6	7.33	7.36	7.56	7.46	+0.10	+ 1.3
		218	49.6	6.75	7.97	8.17	8.07	+0.10	+ 1.2	7.06	8.39	7.79	8.09	-0.30	- 3.7
		232	52.0	6.99	7 36	7 71	7.54	+0.17	+ 2.3	6.49	7.81	6.95	7.38	-0.43	- 5.8
		208	56.0	7.93	8.92	9.33	9.13	+0.20	+ 2.2	7.62	9.41	8.49	8.95	-0.46	- 5.1
		214	56.0	7.23	7.72	8.17	8.00	+0.17	+ 2.1	7.34	8.83	8.13	8.48	-0.35	- 4.1
		205	56.0	7.46	7.96	7.83	7.90	-0.07	- 0.9	7.34	8.82	8.02	8.42	-0.40	- 4.7
		234	58.3	7.47	7.96	7.67	7.80	-0.13	- 1.7	7.92	9.11	8.24	8.68	-0.44	- 5.1
		212	58.8	7.46	7.83	7.67	7.75	-0.08	- 1.0	7.91	9.12	8.49	8.81	-0.32	- 3.6
		214	60.0	7.95	8.07	8.33	8.20	+0.13	+ 1.6	7.48	8.25	7.67	7.96	-0.29	- 3.6
			64.0	7.46	8.19	9.33	8.76	+0.57	+ 6.5	7.90	9.12	8.96	9.04	-0.08	- 0.9
	S3	268	50.0	6.65	7.97	8.01	7.99	+0.02	+ 0.3	6.62	8.69	8.01	8.35	-0.34	- 4.1
		263	54.9	7.01	7.24	8.17	7.71	+0.46	+ 6.0	7.06	8.24	8.96	8.60	+0.36	+ 4.2
		263	60.0	6.66	7.25	7.67	7.46	+0.21	+ 2.8	7.20	8.10	7.31	7.71	-0.40	- 5.2

NOTE: STRESSES SHOWN ARE COMPRESSION VALUES IN KSI AT EXTREME FIBER. A POSITIVE SIGN IN COLUMNS 9,10,15 & 16 SHOWS THAT THE STRESS ON THE INNER EDGE IS GREATER BY THE VALUE SHOWN

TABLE 8

VARIATION OF RECORDED STRESSES ACROSS TOP AND BOTTOM FLANGE 107'-0 THROUGH PLATE GIRDER

GIRDER	TEST LOCOMOTIVE			TOP FLANGE						BOTTOM FLANGE					
	CLASS	NUMBER	SPEED MPH	GAGES			AVER. T2 & T3	VARIATION FROM AVER.		GAGES			AVER. B2 & B3	VARIATION FROM AVER	
				T1	T2	T3		STRESS	%	B1	B2	B3		STRESS	%
COL 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
NORTH		73	18.4	3.60	3.75	3.84	3.39	-0.35	-10.3	3.33	3.17	3.63	3.40	+0.23	+6.8
		110	19.3	4.15	3.98	3.63	3.80	-0.17	-4.5	3.33	2.94	3.40	3.17	+0.23	+7.3
		74	29.3	3.47	3.04	3.51	3.27	+0.24	+7.3	3.33	2.72	3.17	2.94	+0.23	+7.8
		75	34.1	3.35	3.39	3.27	3.33	-0.06	-1.8	3.44	3.17	3.75	3.46	+0.29	+8.4
		109	38.5	3.85	3.86	3.63	3.74	-0.11	-2.9	5.17	3.62	3.98	3.80	+0.18	+4.7
		109	39.4	4.10	3.86	3.75	3.79	-0.04	-1.1	3.94	3.75	3.75	3.75	0.0	0.0
	2 AXLE DIESEL	78	39.6	3.85	3.51	3.75	3.63	+0.12	+3.3	4.19	3.96	4.22	4.09	+0.13	+3.2
		75	41.7	3.72	3.51	3.63	3.57	+0.06	+1.7	3.58	3.29	3.40	3.34	+0.06	+1.8
		109	48.6	3.85	3.51	3.27	3.39	-0.12	-3.5	3.33	3.17	3.40	3.29	+0.11	+3.3
		77	51.7	3.60	3.51	3.51	3.51	0.00	0.0	4.43	3.29	3.63	3.46	+0.17	+4.9
		75	52.2	4.10	3.86	3.86	3.86	0.00	0.0	3.58	3.50	3.40	3.45	-0.05	-1.4
		49	52.5	3.47	3.75	3.16	3.45	-0.29	-8.4	4.06	3.85	4.34	4.09	+0.25	+6.1
		111	56.3	3.85	3.51	3.63	3.57	+0.06	+1.7	3.69	3.40	3.86	3.63	+0.23	+6.3
		110	56.3	3.85	2.93	3.98	3.45	+0.53	+15.4	3.58	3.40	3.75	3.57	+0.18	+5.0
		50	60.6	3.85	3.86	3.75	3.69	+0.06	+1.6	3.69	3.96	4.22	4.09	+0.13	+3.2
	3 AXLE DIESEL	20	89.8	3.47	3.28	2.93	3.10	-0.17	-5.5	3.58	4.07	3.29	3.68	-0.39	-10.6
		18	92.0	3.47	3.39	2.93	3.16	-0.23	-7.3	3.44	3.50	3.05	3.27	-0.22	-6.7
	S2	216	28.1	6.20	5.39	5.85	5.62	+0.23	+4.9	5.17	5.55	5.98	5.76	+0.22	+3.8
		212	38.6	6.33	6.09	5.51	5.80	-0.29	-5.0	7.27	6.00	6.33	6.16	+0.17	+2.8
B3 B1 B2		206	51.7	6.33	5.85	5.74	5.79	-0.05	-0.9	6.15	5.66	6.33	5.99	+0.34	+5.7
	S3	261	28.1	6.45	5.50	6.32	5.91	+0.41	+6.9	5.91	5.89	5.62	5.75	-0.13	-2.3
SOUTH		110	3.5	3.63	3.40	3.63	3.51	+0.12	+3.4	3.33	3.73	3.51	3.62	-0.11	-3.0
		73	3.6	3.40	3.05	3.05	3.05	0.00	0.0	3.57	3.85	3.75	3.80	-0.05	-1.3
		72	13.6	3.51	3.51	3.28	3.39	-0.11	-3.2	3.57	3.62	3.86	3.74	+0.12	+3.2
		49	19.3	3.87	3.28	3.86	3.57	+0.29	+8.1	3.81	3.51	3.75	3.63	+0.12	+3.3
		111	19.9	3.75	3.28	3.51	3.39	+0.12	+3.5	3.81	4.53	3.98	4.25	-0.27	-6.4
T2 T1 T3		110	27.5	4.12	3.51	3.98	3.74	+0.24	+6.4	3.57	4.19	3.86	4.02	-0.16	-4.0
	2 AXLE DIESEL	109	37.3	3.51	3.17	3.28	3.22	+0.06	+1.9	3.69	4.19	4.10	4.14	-0.04	-0.9
		78	39.0	3.75	2.93	4.22	3.57	+0.65	+18.2	3.57	3.96	3.86	3.91	-0.05	-1.3
		78	43.0	3.63	3.51	3.51	3.51	0.00	0.0	3.20	3.85	3.40	3.62	-0.22	-6.1
		73	48.2	3.63	3.05	3.75	3.40	+0.35	+10.3	3.44	3.62	3.75	3.68	+0.07	+1.9
		70	49.3	3.75	3.40	3.28	3.34	-0.06	-1.8	3.20	3.96	3.40	3.68	-0.28	-7.6
		70	57.2	3.87	3.86	3.86	3.86	0.00	0.0	3.69	3.62	3.51	3.56	-0.05	-1.4
		106	61.2	3.63	3.75	3.51	3.63	-0.12	-3.3	3.33	3.51	3.17	3.34	-0.17	-5.1
		19	7.1	3.15	2.81	3.28	3.04	+0.24	+7.9	2.58	3.06	2.69	2.87	-0.18	-6.3
	3 AXLE DIESEL	19	88.7	3.27	2.81	3.40	3.10	+0.30	+9.7	3.08	3.40	3.17	3.28	-0.11	-3.4
		20	90.9	3.27	2.58	3.74	3.16	+0.58	+18.3	2.96	3.17	3.28	3.22	+0.06	+1.9
		20	92.1	3.27	2.46	3.86	3.16	+0.70	+22.2	2.96	3.40	3.40	3.40	0.00	0.0
		20	93.3	3.03	2.11	3.86	2.98	+0.88	+29.5	3.08	3.29	3.05	3.17	-0.12	-3.8
	S2	208	4.9	5.94	5.15	6.10	5.62	+0.48	+8.5	5.29	6.12	5.74	5.93	-0.19	-3.2
		208	9.2	6.67	5.86	6.44	6.15	+0.29	+4.7	5.29	6.22	5.62	5.92	-0.30	-5.1
		208	16.1	6.54	5.62	6.68	6.15	+0.53	+8.6	5.79	6.68	6.20	6.44	-0.24	-3.7
		216	26.3	6.05	5.62	5.04	5.33	-0.29	-5.4	5.54	6.22	6.32	6.27	+0.05	+0.8
		217	28.9	6.90	5.86	6.79	6.32	+0.47	+7.4	5.91	6.79	6.33	6.56	-0.23	-3.5
		208	45.8	6.67	6.33	6.56	6.44	+0.12	+1.9	6.15	6.45	6.44	6.44	0.00	0.0
		216	51.7	6.18	5.51	6.33	5.92	+0.41	+5.9	6.15	6.34	6.32	6.33	-0.01	-0.2
B2 B1 B3	S3	264	8.4	5.82	5.28	5.62	5.45	+0.17	+3.1	5.66	6.00	5.98	5.99	-0.01	-0.2
			11.8	6.05	5.28	6.20	5.74	+0.46	+8.0	5.79	6.45	6.20	6.32	-0.12	-1.9
			26.6	6.18	5.62	6.10	5.86	+0.24	+4.1	5.66	6.22	6.10	6.16	-0.06	-1.0
			30.1	6.30	5.86	6.33	6.09	+0.24	+3.9	5.91	7.13	6.20	6.66	-0.46	-6.9

NOTE: COLUMN 5,6 & 7 ARE RECORDED COMPRESSIVE VALUES IN KSI. COLUMNS 11,12 & 13 ARE RECORDED TENSILE VALUES IN KSI. ALL VALUES ARE AT EXTREME FIBER.
A POSITIVE SIGN IN COLUMNS 9,10,15 & 16 SHOWS THAT THE STRESS ON THE INNER EDGE IS GREATER BY THE VALUE SHOWN.

TABLE 9

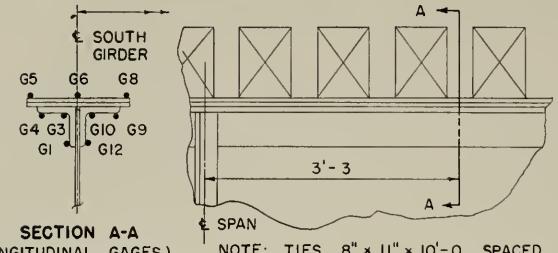
VARIATION OF RECORDED STRESSES ACROSS TOP AND BOTTOM FLANGE 140'-0 THROUGH PLATE GIRDER

GIRDER	TEST LOCOMOTIVE			TOP FLANGE						BOTTOM FLANGE					
	CLASS	NUMBER	SPEED MPH	GAGES			AVER. T2 & T3	VARIATION FROM AVER.		GAGES			AVER B2 & B3	VARIATION FROM AVER.	
				T1	T2	T3		STRESS	%	B1	B2	B3		STRESS	%
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
NORTH		110	3.8	3.69	4.26	3.81	4.04	-0.23	- 5.7	3.36	3.58	3.51	3.55	-0.04	- 1.1
T3 T1 T2		76	23.4	3.81	4.37	3.92	4.15	-0.23	- 5.5	2.81	3.14	3.40	3.27	+0.13	+ 4.0
		72	24.9	3.46	4.60	3.92	4.26	-0.34	- 8.0	2.71	3.03	3.30	3.17	+0.13	+ 4.1
	2 AXLE	78	27.8	3.11	4.26	3.46	3.86	-0.40	-10.4	2.71	3.25	3.40	3.33	+0.07	+ 2.1
	DIESEL	69	48.8	3.34	4.05	3.69	3.87	-0.18	- 4.7	3.58	3.58	3.40	3.49	-0.09	- 2.6
		110	49.1	3.69	4.49	3.69	4.09	-0.40	- 9.8	2.81	3.90	3.62	3.76	-0.14	- 3.7
		69	49.1	3.69	4.26	3.81	4.04	-0.23	- 5.7	3.36	3.58	3.51	3.55	-0.04	- 1.1
		59	56.4	3.34	4.37	3.58	3.98	-0.40	-10.1	3.25	3.58	3.73	3.66	+0.07	+ 1.9
		76	60.0	3.46	4.15	3.69	3.92	-0.23	- 5.9	2.71	3.36	3.51	3.44	+0.07	+ 2.0
		429	6.5	3.92	4.80	4.04	4.42	-0.38	- 8.6	2.92	3.58	3.83	3.71	+0.12	+ 3.2
		469	12.5	3.92	4.80	3.81	4.31	-0.50	-11.6	3.36	3.69	3.19	3.44	-0.25	- 7.3
	L28	469	15.1	3.92	4.49	4.15	4.32	-0.17	- 3.9	3.47	4.00	4.15	4.08	+0.07	+ 1.7
		439	16.2	3.92	4.05	4.84	4.45	+0.39	+ 8.8	2.92	3.36	3.62	3.49	+0.13	+ 3.7
		439	30.1	4.26	4.60	4.84	4.72	+0.12	+ 2.5	3.80	4.33	4.69	4.51	+0.18	+ 4.0
		424	40.7	4.15	5.58	3.92	4.75	-0.83	-17.5	3.80	4.11	3.94	4.03	-0.09	- 2.2
B3 B1 B2	S2	231	47.4	5.88	6.22	6.00	6.11	-0.11	- 1.8	5.21	5.63	5.32	5.48	-0.16	- 2.9
	S3	268	47.8	5.76	6.01	6.92	6.46	+0.46	+ 7.1	5.42	5.75	6.06	5.91	+0.15	+ 2.5
SOUTH		110	14.6	3.00	4.26	4.04	4.15	-0.11	- 2.7	3.34	3.47	3.40	3.44	-0.04	- 1.2
		50	29.2	3.76	4.70	4.39	4.55	-0.16	- 3.5	4.26	3.80	3.94	3.87	+0.07	+ 1.8
		109	34.3	3.98	4.26	4.61	4.44	+0.17	+ 3.8	3.92	4.11	3.78	3.92	-0.19	- 4.9
		70	36.7	3.54	4.15	3.81	3.98	-0.17	- 4.3	3.58	3.47	3.19	3.33	-0.14	- 4.2
T2 T1 T3		89	51.2	3.87	4.37	3.92	4.15	-0.23	- 5.5	3.69	3.90	3.73	3.82	-0.09	- 2.4
	2 AXLE	77	55.2	4.40	4.92	4.39	4.66	-0.27	- 5.8	3.46	3.47	3.19	3.33	-0.14	- 4.2
	DIESEL	108	56.1	3.65	3.50	4.73	4.12	+0.61	+14.8	3.46	3.36	3.62	3.49	+0.13	+ 3.7
		108	56.7	3.76	4.48	3.69	4.09	-0.40	- 9.8	4.04	4.01	3.51	3.76	-0.25	- 6.6
		49	57.0	3.69	4.37	4.04	4.21	-0.17	- 4.0	3.46	3.90	3.51	3.71	-0.20	- 5.4
		72	57.2	3.55	4.15	3.69	3.92	-0.23	- 5.9	3.46	3.69	3.51	3.60	-0.09	- 2.5
		71	58.0	3.76	4.03	3.85	3.94	-0.09	- 2.3	4.37	4.11	4.04	4.08	-0.04	- 1.0
		108	58.1	3.44	4.05	3.69	3.87	-0.18	- 4.7	3.58	3.80	3.62	3.71	-0.09	- 2.4
		541	12.3	4.19	4.59	4.49	4.54	-0.05	- 1.1	4.15	4.44	3.94	4.19	-0.25	- 6.0
		469	20.4	4.19	5.25	3.92	4.59	-0.67	-14.6	4.15	4.55	3.51	4.03	-0.52	-12.9
	L28	541	26.3	4.30	5.35	3.46	4.41	-0.95	-21.5	3.69	3.90	3.73	3.82	-0.09	- 2.4
		541	30.5	4.61	5.69	4.04	4.87	-0.83	-17.1	4.15	4.55	3.73	4.14	-0.41	- 9.9
		541	39.5	4.84	5.69	5.07	5.38	-0.31	- 5.8	4.61	5.09	4.36	4.73	-0.37	- 7.8
		468	43.1	4.19	5.25	4.39	4.82	-0.43	- 8.9	3.81	4.11	3.83	3.97	-0.14	- 3.5
		215	18.9	5.05	6.13	6.80	6.47	+0.33	+ 5.1	5.07	5.20	5.44	5.32	+0.12	+ 2.3
		203	27.5	5.69	6.89	6.80	6.85	-0.05	- 0.7	6.11	5.96	5.64	5.80	-0.16	- 2.8
	S2	230	31.8	6.66	6.13	8.41	7.27	+1.14	+15.7	6.69	6.72	6.70	6.71	-0.01	- 0.1
		230	52.0	6.55	7.00	7.49	7.25	+0.24	+ 3.3	6.34	6.28	6.17	6.23	-0.06	- 1.0
		215	56.7	5.69	7.11	7.04	7.08	-0.04	- 0.6	6.23	6.06	5.75	5.91	-0.16	- 2.7
		268	8.4	5.26	5.90	6.92	6.41	+0.51	+ 8.0	5.65	5.75	5.83	5.79	+0.04	+ 0.7
		265	21.5	6.23	6.67	7.14	6.91	+0.23	+ 3.3	5.89	6.28	6.06	6.17	-0.11	- 1.8
	S3	268	28.7	5.90	6.78	8.07	7.43	+0.64	+ 8.6	6.46	6.17	6.17	6.17	0	0
		266	29.6	6.01	6.34	7.15	6.75	+0.40	+ 5.9	6.23	6.61	6.06	6.34	-0.28	- 4.4
		266	49.8	6.23	6.01	7.14	6.58	+0.56	+ 8.5	6.00	6.06	6.17	6.12	+0.05	+ 0.8
B2 B1 B3		260	51.7	5.90	6.34	6.46	6.40	+0.06	+ 0.9	5.54	5.85	5.53	5.69	-0.16	- 2.8

NOTE: COLUMNS 5,6 & 7 ARE RECORDED COMPRESSIVE VALUES IN KSI. COLUMNS 11,12 & 13 ARE RECORDED TENSILE VALUES IN KSI. ALL VALUES ARE AT EXTREME FIBER.
A POSITIVE SIGN IN COLUMNS 9, 10, 15 & 16 SHOWS THAT THE STRESS ON THE INNER EDGE IS GREATER BY THE VALUE SHOWN.

TABLE 10

STRESS DISTRIBUTION IN TOP FLANGE OF 55'-0 DECK GIRDER



SECTION A-A (LONGITUDINAL GAGES)

NOTE: TIES 8" × 11" × 10'-0 SPACED AT 12" CENTERS AND IN FULL BEARING ON FLANGES

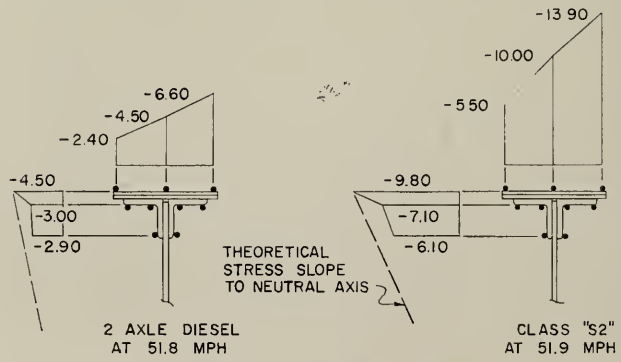
SECTION A-A (TRANSVERSE GAGES)

TEST LOCOMOTIVE		RUN NUMBER	SPEED IN MPH	"Q" RECORDED STRESS AT GAGE 6 IN KSI	RATIO OF RECORDED STRESS TO "Q"									RECORDED STRESS IN KSI		
CLASS	NUMBER				G1/Q	G3/Q	G4/Q	G5/Q	G6/Q	G8/Q	G9/Q	G10/Q	G12/Q	G2	G7	G11
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2 AXLE DIESELS	85	123	18.1	4.30	0.40	0.70	0.51	0.72	1.00	1.47	0.84	0.72	0.60	0.80	+3.10	0.80
	74	135	43.1	4.70	0.40	0.64	0.55	0.40	1.00	1.47	0.77	0.66	0.57	0.90	+3.00	1.30
	77	131	46.1	5.00	0.46	0.64	0.60		1.00	1.34	0.70	0.64	0.54	0.20	+4.80	0.90
	70	128	51.8	4.50	0.69	0.60	0.62	0.53	1.00	1.47	0.73	0.71	0.60	0.40	+3.40	1.60
	93	120	58.4	4.80	0.50	0.69	0.58		1.00	1.42	0.81	0.73	0.56	0.80	+3.00	0.80
3 AXLE	21	119	7.2	4.80	0.62	0.75	0.60	0.58	1.00	1.46	0.79	0.75	0.58	0.50	+2.60	0.90
	21	139	81.0	4.90	0.75	0.65	0.61	0.39	1.00	1.45	0.73	0.67	0.59	0.50	+4.90	0.80
S2	236	127	38.8	8.30	0.58	0.67	0.61		1.00	1.56	0.84	0.71	0.64	0.40	+8.40	1.10
	201	118	47.6	8.90	0.66	0.74	0.67	0.58	1.00	1.33	0.76	0.62	0.61			
	215	121	51.9	10.00	0.58	0.73	0.60	0.55	1.00	1.39	0.79	0.71	0.64	+0.30	+8.60	0.70
	220	125	54.3	9.60	0.61	0.74	0.58	0.83	1.00	1.30	0.72	0.70	0.64	+0.80	+6.10	0.30
	232	137	60.6	8.50	0.58	0.71	0.62	0.53	1.00	1.41	0.71	0.67	0.59	+0.30	+5.50	0.20

NOTES: RECORDED STRESS FOR GAGES 1, 3, 4, 5, 6, 8, 9, 10 & 12 OCCURED WHEN STRESS AT GAGE 8 WAS MAXIMUM.

RECORDED STRESS FOR GAGES 2, 7, & 11 OCCURED WHEN STRESS AT GAGE 7 WAS MAXIMUM.

ALL VALUES ARE COMPRESSIVE EXCEPT WHERE NOTED



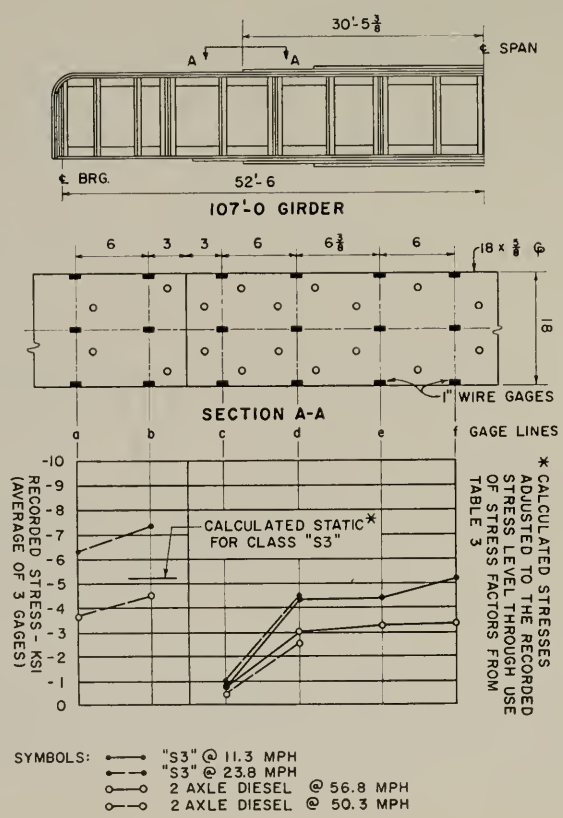
2 AXLE DIESEL AT 51.8 MPH

CLASS "S2" AT 51.9 MPH

TYPICAL RECORDED STRESS DISTRIBUTION

TABLE 11

LONGITUDINAL STRESS DISTRIBUTION AT END OF COVER PLATES



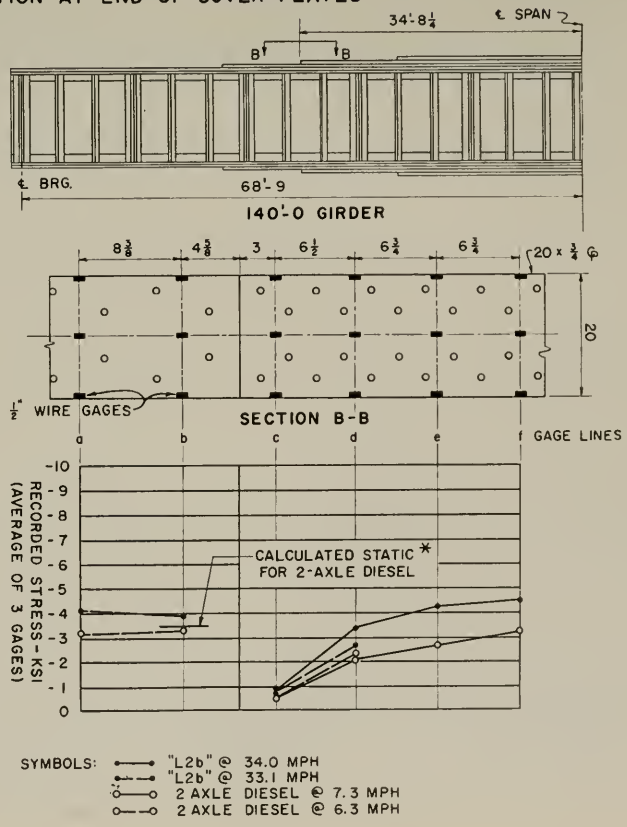


TABLE 12

C.M.ST.P. & P. RR. BRIDGE TESTS

RECORDED MAXIMUM STRESSES IN LATERALS AND CROSSFRAMES

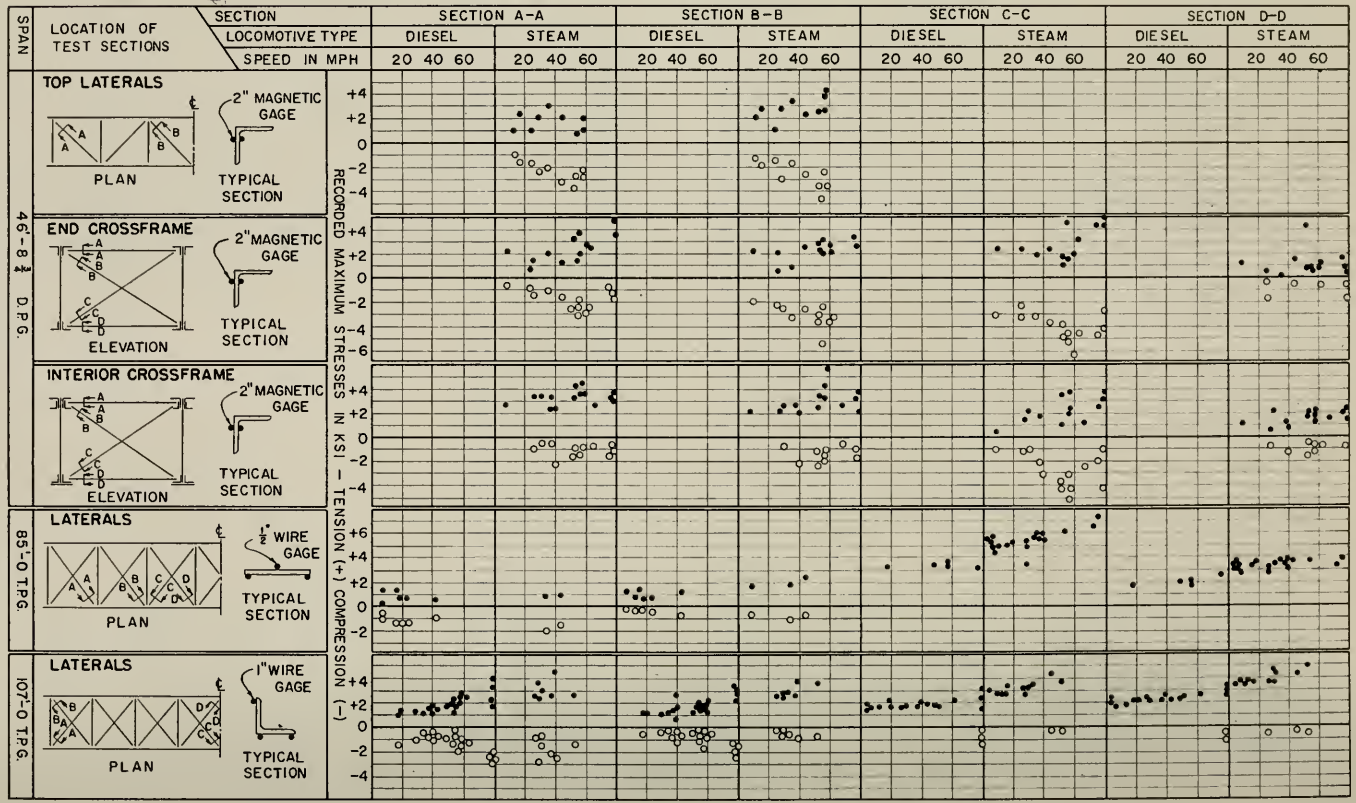


TABLE 13

C.M.ST.P. & P. RR BRIDGE TESTS

RECORDED MAXIMUM STRESSES IN LATERALS AND CROSSFRAMES

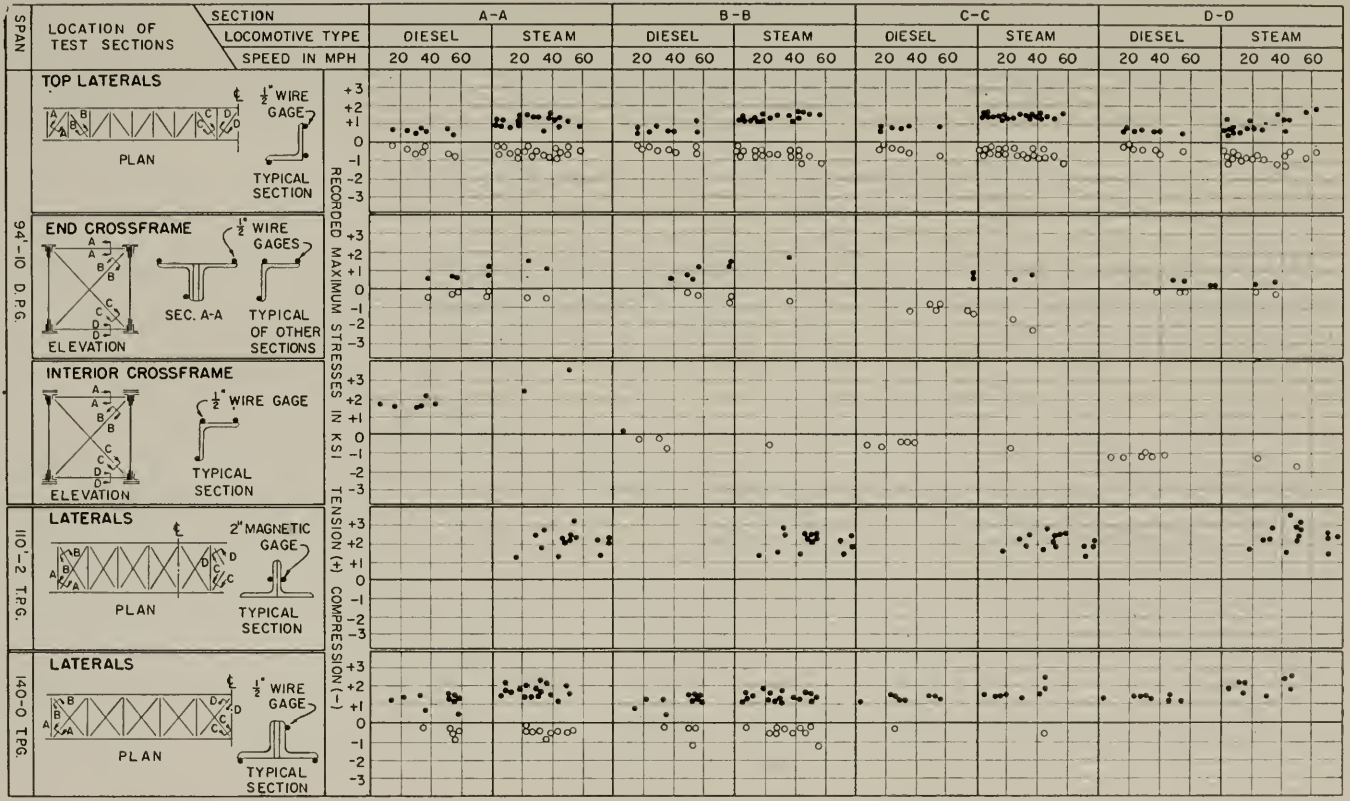
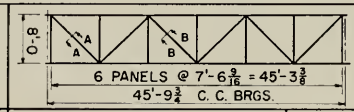


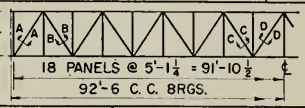
TABLE 14

COMPARISON OF RECORDED AND CALCULATED STRESSES IN LATERALS

TOP LATERALS (LOCATION OF GAGES)



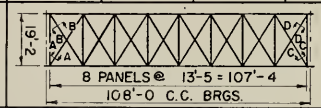
46'-8 3/4" DPG
2" MAGNETIC GAGE
SECTION



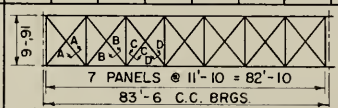
94'-10 DPG
1/2" WIRE GAGE
SECTION

SECTION	A-A			B-B			A-A			B-B			C-C			D-D		
LOCOMOTIVE CLASS & SPEED IN MPH	"A" 43.7	"S2" 35.5	"S3" 51.5	"A" 58.8	"S2" 35.5	"S3" 53.4	2-AX 55.2	3-AX 36.8	"S2" 23.4	2-AX 55.2	3-AX 15.9	"S2" 17.7	2-AX 55.2	3-AX 36.0	"S2" 40.5	2-AX 27.6	3-AX 15.9	"S2" 57.3
RECORDED MAX. STRESS	-3.12	+2.93	-3.84	+4.37	+3.45	-4.64	+0.77	+0.70	+1.60	+1.02	+0.78	+1.58	+0.93	+0.95	+1.60	+0.77	+0.77	+1.83
CALC. CORRES. LATERAL LOAD	11.5	10.8	14.1	21.1	16.6	22.4	4.9	4.5	10.2	6.9	5.3	10.7	8.1	8.3	14.0	7.5	7.5	17.7
CALC. AREA-NOSING	5.45	5.45	5.45	4.16	4.16	4.16	3.15	3.15	3.15	2.97	2.97	2.97	2.30	2.30	2.30	2.07	2.07	2.07
CALC. AREA-TRANSV. SHEAR	1.74	2.64	2.44	3.61	5.47	5.07	0.55	0.61	0.99	0.99	1.10	1.79	2.71	3.03	4.92	2.71	3.05	4.92
CALC. TOTAL	7.19	8.09	7.89	7.77	9.63	9.23	3.70	3.76	4.14	3.96	4.07	4.76	5.01	5.33	7.22	4.78	5.12	6.99

BOTTOM LATERALS (LOCATION OF GAGES)



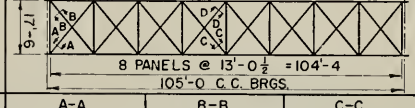
110'-2 TPG
2" MAGNETIC GAGE
SECTION



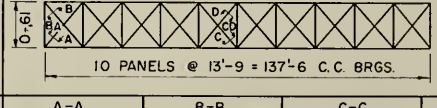
85'-0 TPG
1/2" WIRE GAGE
SECTION

SECTION	A-A				B-B				C-C				D-D				A-A				B-B				C-C				D-D			
LOCOMOTIVE CLASS & SPEED IN MPH	"A" 80.5	"L26" 34.4	"S2" 55.2	"S3" 51.5	"A" 80.5	"L26" 32.5	"S2" 46.9	"S3" 51.5	"A" 82.0	"L26" 34.4	"S2" 46.9	"S3" 51.5	"A" 80.5	"L26" 34.4	"S2" 46.9	"S3" 51.5	2-AX 15.5	3-AX 22.3	"L26" 34.1		2-AX 15.5	3-AX 6.5	"L26" 43.2		2-AX 57.2	3-AX 17.9	"L26" 27.6	"S3" 74.0	2-AX 57.2	3-AX 75.5	"L26" 27.2	"S3" 74.0
RECORDED MAX. STRESS	+2.36	+2.71	+3.14	+2.22	+2.42	+2.98	+2.57	+2.34	+2.10	+2.46	+2.89	+1.95	+2.47	+2.95	+3.57	+2.03	±1.13	-1.35	-2.02		+1.38	+1.25	+2.42		+3.53	+3.20	+4.97	+7.20	+2.10	+2.60	+3.12	+3.90
CALC. CORRES. LATERAL LOAD	14.4	16.5	19.1	13.5	14.7	18.1	15.6	14.2	22.3	26.1	30.6	20.7	26.2	31.3	37.8	21.5	3.2	3.8	5.7		4.7	4.3	8.2		15.0	13.6	21.1	30.6	8.9	11.0	13.3	16.6
CALC. AREA-NOSING	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	7.07	7.07	7.07		5.88	5.88	5.88		4.73	4.73	4.73	4.73	4.73	4.73	4.73	4.73

BOTTOM LATERALS (LOCATION OF GAGES)



107'-0 TPG
1" WIRE GAGE
SECTION



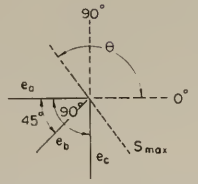
140'-0 TPG
1/2" WIRE GAGE
SECTION

SECTION	A-A				B-B				C-C				D-D				A-A				B-B				C-C				D-D			
LOCOMOTIVE CLASS & SPEED IN MPH	2-AX 60.6	3-AX 89.8	"S2" 39.6	"S3" 28.1	2-AX 39.6	3-AX 78.7	"S2" 39.6	"S3" 28.1	2-AX 19.3	3-AX 90.9	"S2" 45.8	"S3" 30.1	2-AX 61.2	3-AX 90.9	"S2" 51.7	"S3" 30.1	2-AX 51.2	"L26" 12.3	"S2" 52.0	"S3" 8.4	2-AX 51.2	"L26" 12.3	"S2" 18.9	"S3" 8.4	2-AX 49.1	"L26" 40.7	"S2" 47.4	"S3" 47.8	2-AX 23.4	"L26" 40.7	"S2" 47.4	"S3" 47.8
RECORDED MAX. STRESS	+2.50	+4.00	+4.60	+2.44	+2.76	+3.47	+3.80	+2.56	+2.20	+3.10	+4.33	+3.27	+2.70	+3.13	+4.97	+4.43	+1.67	+1.73	+2.27	+2.13	+1.53	+1.43	+1.90	+1.60	+1.43	+1.60	+2.40	+1.87	+1.43	+2.30	+1.77	+2.40
CALC. CORRES. LATERAL LOAD	8.6	13.7	15.8	8.4	9.5	11.9	13.0	8.8	10.0	14.1	19.8	14.9	12.3	14.3	22.6	20.2	14.3	14.8	19.4	18.2	13.1	12.2	16.3	13.7	22.0	24.6	36.9	28.8	22.0	35.4	27.3	36.9
CALC. AREA-NOSING	5.82	5.82	5.82	5.82	5.82	5.82	5.82	5.82	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30

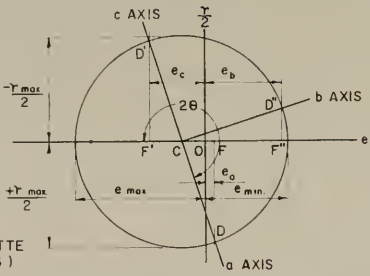
NOTE : STRESSES ARE CALCULATED ON GROSS SECTION.
STRESSES ARE GIVEN IN KSI AND MOVING LATERAL LOADS IN KIPS.
NOSING AND TRANSVERSE SHEAR STRESSES ARE EITHER TENSION (+) OR COMPRESSION (-).
FOR THE CALCULATED VALUES ON THE 85'-0 T.P.G., IT WAS ASSUMED THAT THE LATERALS COULD NOT TAKE COMPRESSION.

TABLE 15

STUDY OF STRAIN ROSETTE GAGES ON GIRDER - WEBS



RECTANGULAR OR 45° ROSETTE
(1 IN SR-4 TYPE AR-1 GAGES)



MOHR'S CIRCLE (FOR STRAIN)

DESIGNATION OF SYMBOLS:

E = 30,000,000 psi μ = 0.285 (POISSON'S RATIO)
e = UNIT STRAINS ALONG GAGE AXIS
R = UNIT STRAINS READ BY INSTRUMENT (APPARENT STRAIN)
GAGE FACTOR = 2.06 (USED TO DETERMINE R) } SUPPLIED BY GAGE
AUXILIARY FACTOR = 55 } MANUFACTURER

$e_a = R_a - \frac{1}{55} R_c$ $e_b = 1.015\, R_b - \frac{1}{55}(R_a + R_b)$ $e_c = R_c - \frac{1}{55} R_a$

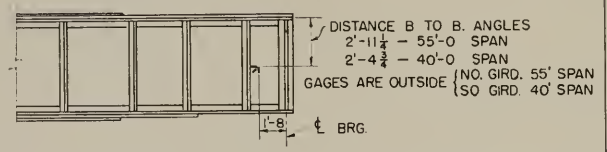
$S_{max.} = \frac{(e_{max} + \mu e_{min})E}{1 - \mu^2}$ (MAXIMUM PRINCIPAL NORMAL STRESS)

$q = \frac{E e_{s\,max}}{2(1 + \mu)}$ (PRINCIPAL SHEARING STRESS)

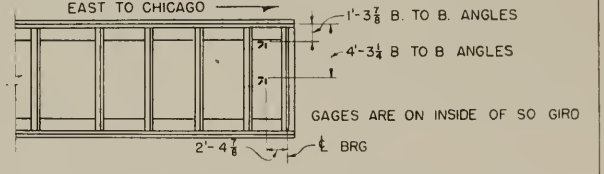
θ = ANGLE COUNTERCLOCKWISE FROM 0° AXIS AT WHICH PRINCIPAL STRESS OCCURS
$R_b E$ = VALUE OF MAX. RECORDED STRESS IF ONLY "b" GAGE WAS USED
FOR DIRECT STRESSES & STRAINS, (+) = TENSION & (-) = COMPRESSION
FOR SHEAR STRESSES & STRAINS, (+) = CLOCKWISE & (-) = COUNTERCLOCKWISE

LOCATION OF GAGES

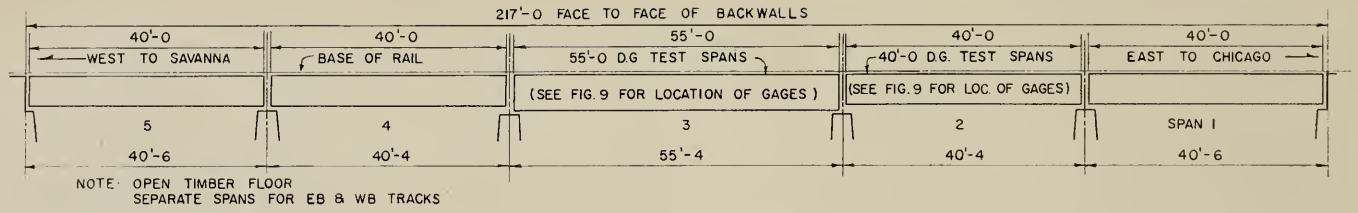
55'-0 & 40'-0 EASTBOUND SPANS



94'-10 SPAN

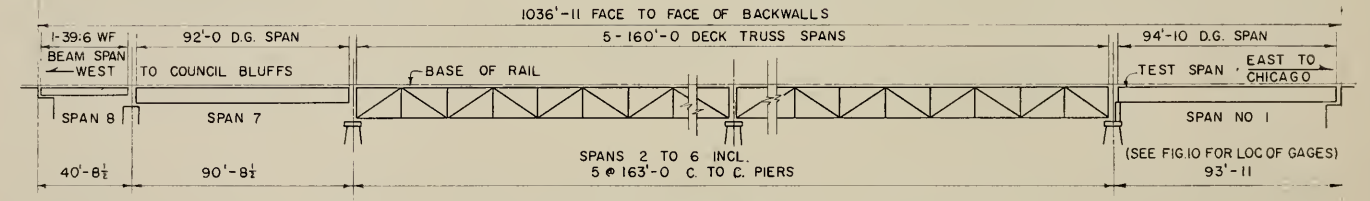


LOCO & SPEED	55'-0 SPAN: 3 AXLE 2 UNIT DIESEL AT 82.4 MPH	55'-0 SPAN: S2 STEAM LOCO. AT 51.3 MPH	40'-0 SPAN: 3 AXLE 2 UNIT DIESEL AT 82.4 MPH	40'-0 SPAN: S2 STEAM LOCO. AT 51.3 MPH	TOP GAGES: 3 AXLE 2 UNIT DIESEL AT 56.3 MPH	TOP GAGES: S2 STEAM LOCO. AT 57.3 MPH	CENTER GAGES: 3 AXLE 2 UNIT DIESEL AT 56.3 MPH	CENTER GAGES: S2 STEAM LOCO AT 34.6 MPH
e_a	$+0.205 \times 10^{-4}$ IN	$+0.205 \times 10^{-4}$	$+0.003 \times 10^{-4}$	$+0.338 \times 10^{-4}$	-0.184×10^{-4}	-0.266×10^{-4}	$+0.052 \times 10^{-4}$	$+0.087 \times 10^{-4}$
e_b	$+1.421 \times 10^{-4}$ IN	$+2.166 \times 10^{-4}$	$+1.383 \times 10^{-4}$	$+2.438 \times 10^{-4}$	$+0.765 \times 10^{-4}$	$+1.205 \times 10^{-4}$	$+0.848 \times 10^{-4}$	$+1.435 \times 10^{-4}$
e_c	-0.270×10^{-4} IN	-0.270×10^{-4}	-0.167×10^{-4}	-0.239×10^{-4}	$+0.003 \times 10^{-4}$	$+0.005 \times 10^{-4}$	-0.134×10^{-4}	-0.185×10^{-4}
S_{max}	− 3500 psi	− 5250	− 3790	+5830	− 2290	− 3690	− 2260	− 3700
S_{min}	+ 3300 psi	+5000	+ 3100	− 5420	+ 1470	+2550	+ 1960	+ 3290
q	± 3360 psi	± 5100	± 3420	± 5620	± 1860	± 3090	± 2050	± 3460
θ	130.5°	132.0°	133.2°	41.5°	138.0°	138.0°	132.0°	132.2°
$R_b E$	+ 4200 psi	+6400	+ 4100	+ 7200	+ 2250	+3550	+ 2500	+ 3950



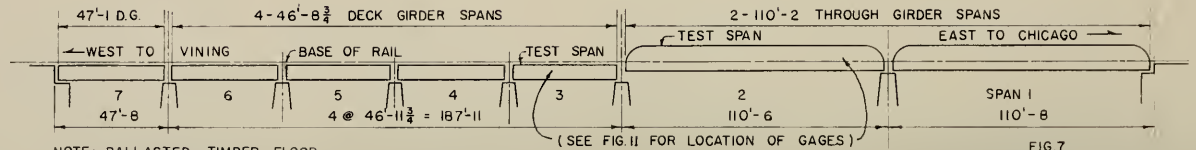
ELEVATION

BRIDGE Z-204, OVER KISHWAUKEE RIVER, $\frac{3}{4}$ MI. WEST OF GENOA, ILL.



ELEVATION

BRIDGE Z-814, OVER CEDAR RIVER, 1.8 MI. EAST OF COVINGTON, IOWA



NOTE: BALLASTED TIMBER FLOOR
SINGLE TRACK
C. TO C. GIRDERS:
SPAN 2: 19'-2 SPAN 3: 8'-0

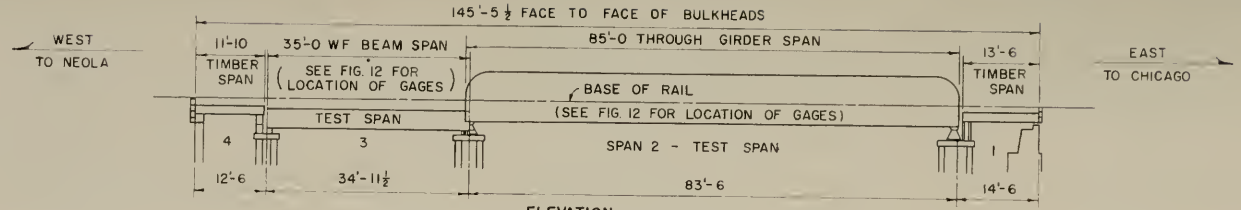
ELEVATION

BRIDGE Z-882 OVER SALT CREEK AT ALBERON, IA.

FIG.7

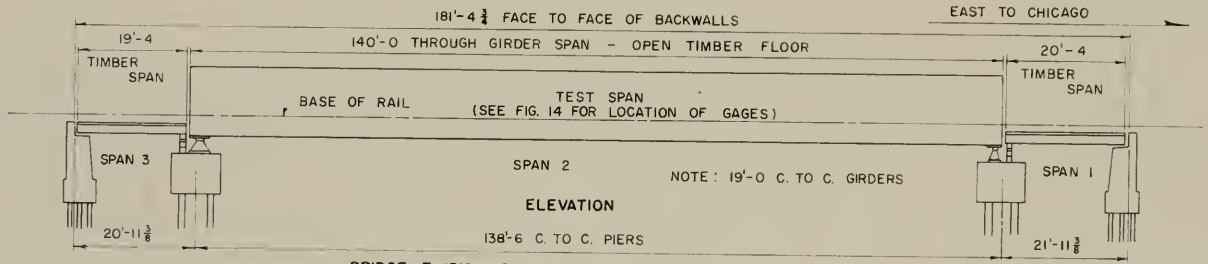
C.M.ST.P. & P. RR. BRIDGE TESTS
40'-0 DECK GIRDER SPAN - OPEN FLOOR
46'-8¾ DECK GIRDER SPAN - BALLASTED FLOOR
55'-0 DECK GIRDER SPAN - OPEN FLOOR
94'-10 DECK GIRDER SPAN - OPEN FLOOR
110'-2 THROUGH GIRDER SPAN - BALLASTED FLOOR

LOCATION OF TEST SPANS

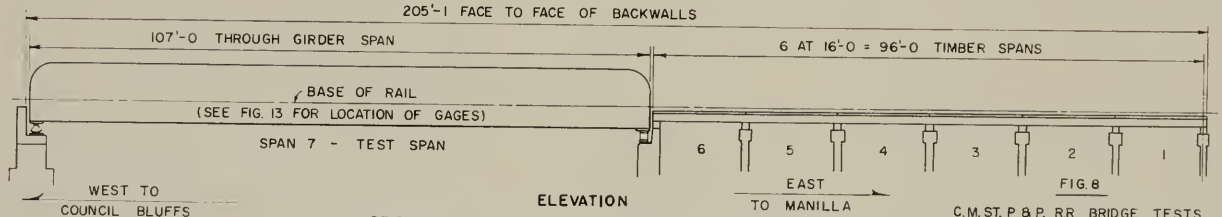


ELEVATION

BRIDGE Z-1500, 1.7 MILES WEST OF PERSIA, IOWA



BRIDGE Z-1510, 0.8 MILE WEST OF YORKSHIRE, IOWA



ELEVATION

BRIDGE Z-1566, 0.5 MILE WEST OF WESTON, IOWA

FIG. 8

C.M.ST.P.&P. R.R. BRIDGE TESTS
35'-0 BEAM SPAN - BALLASTED TRACK
85'-0 THROUGH GIRDER SPAN - BALLASTED FLOOR
107'-0 THROUGH GIRDER SPAN - BALLASTED FLOOR
140'-0 THROUGH GIRDER SPAN - BALLASTED FLOOR

LOCATION OF TEST SPANS

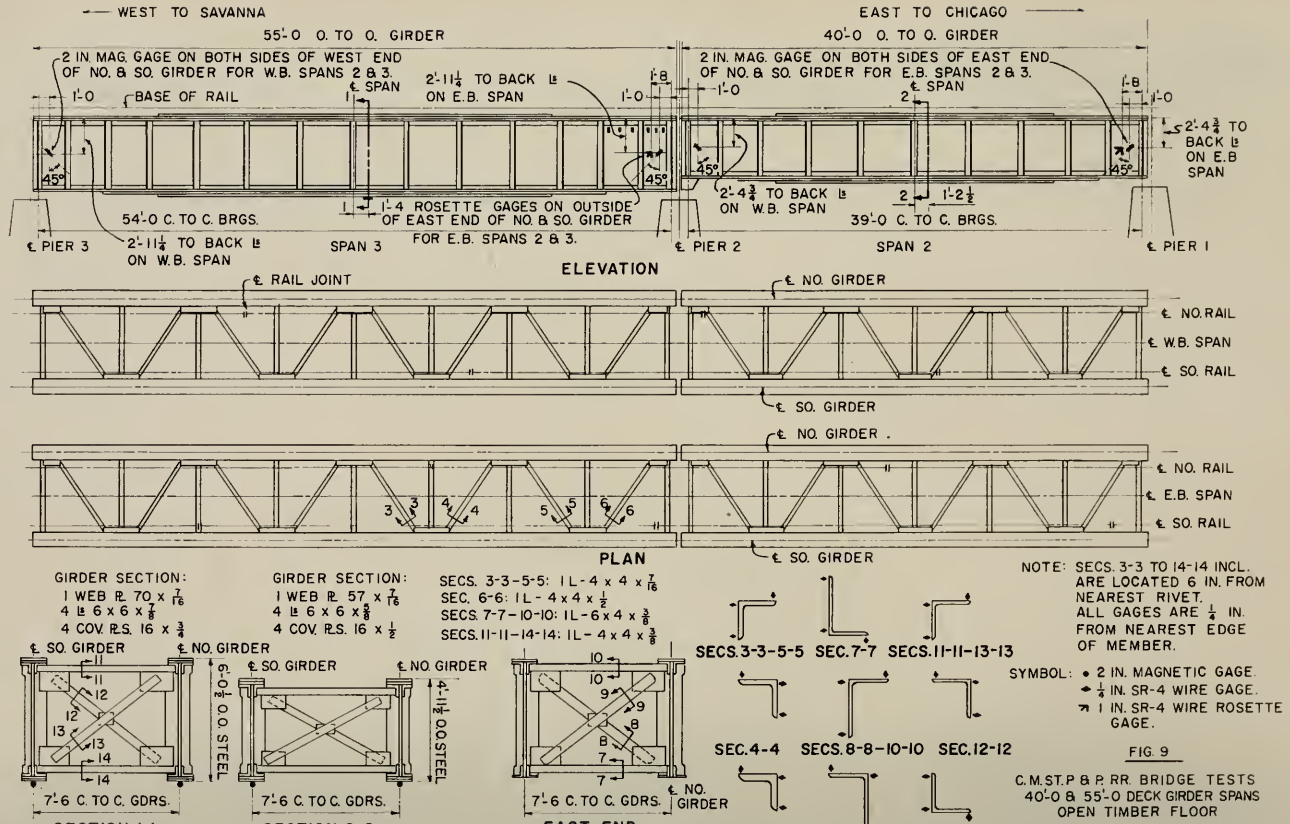
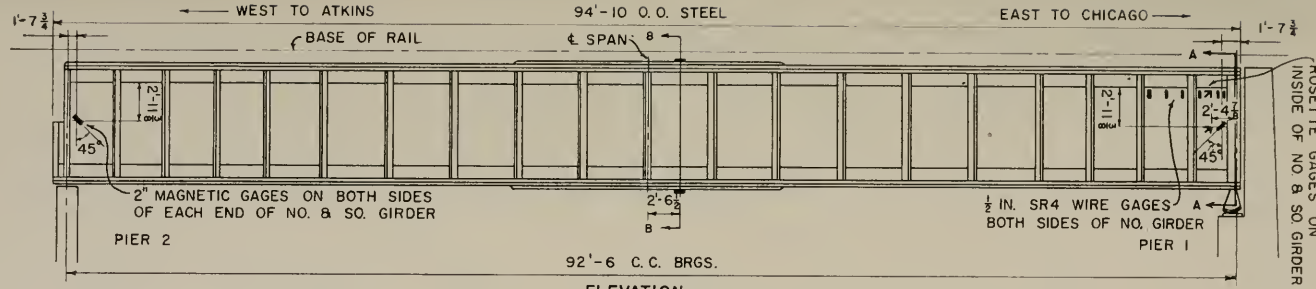

WEST TO SAVANNA
EAST TO CHICAGO
55'-0 O. TO O. GIRDER
40'-0 O. TO O. GIRDER
2 IN. MAG. GAGE ON BOTH SIDES OF WEST END OF NO. & SO. GIRDER FOR W.B. SPANS 2 & 3.
2 IN. MAG. GAGE ON BOTH SIDES OF EAST END OF NO. & SO. GIRDER FOR E.B. SPANS 2 & 3.
BASE OF RAIL
2'-11¼ TO BACK ℄ ON E.B. SPAN
2'-4¾ TO BACK ℄ ON E.B SPAN
2'-4¾ TO BACK ℄ ON W.B. SPAN
1'-4 ROSETTE GAGES ON OUTSIDE OF EAST END OF NO. & SO. GIRDER FOR E.B. SPANS 2 & 3.
54'-0 C. TO C. BRGS.
39'-0 C. TO C. BRGS.
2'-11¼ TO BACK ℄ ON W.B. SPAN
℄ PIER 3
SPAN 3
℄ PIER 2
SPAN 2
℄ PIER 1
45°
ELEVATION
℄ RAIL JOINT
℄ NO. GIRDER
℄ SO. GIRDER
℄ NO. RAIL
℄ W.B. SPAN
℄ SO. RAIL
℄ E.B. SPAN
PLAN
GIRDER SECTION:
1 WEB PL. 70 x 7/16
4 L 6 x 6 x 7/8
4 COV. PLS. 16 x 3/4
GIRDER SECTION:
1 WEB PL. 57 x 7/16
4 L 6 x 6 x 7/8
4 COV. PLS. 16 x 1/2
SECS. 3-3-5-5: 1 L-4 x 4 x 7/16
SEC. 6-6: 1 L-4 x 4 x 1/2
SECS. 7-7-10-10: 1 L-6 x 4 x 3/8
SECS. 11-11-14-14: 1 L-4 x 4 x 3/8
6'-0¾ O.O. STEEL
4'-11½ O.O. STEEL
7'-6 C. TO C. GDRS.
SECTION 1-1
E.B. & W.B. TRACKS
SECS. 11-11 TO 14-14 ON E.B. TRACK
SECTION 2-2
E.B. & W.B. TRACKS
EAST END CROSS FRAME
SPAN 3-E.B. TRACK
SECS. 3-3-5-5
SEC. 7-7
SECS. 11-11-13-13
SEC. 4-4
SECS. 8-8-10-10
SEC. 12-12
SEC. 6-6
SEC. 9-9
SEC. 14-14
NOTE: SECS. 3-3 TO 14-14 INCL. ARE LOCATED 6 IN. FROM NEAREST RIVET. ALL GAGES ARE ¼ IN. FROM NEAREST EDGE OF MEMBER.
SYMBOL: • 2 IN. MAGNETIC GAGE
⬌ ¼ IN. SR-4 WIRE GAGE.
⬎ 1 IN. SR-4 WIRE ROSETTE GAGE.

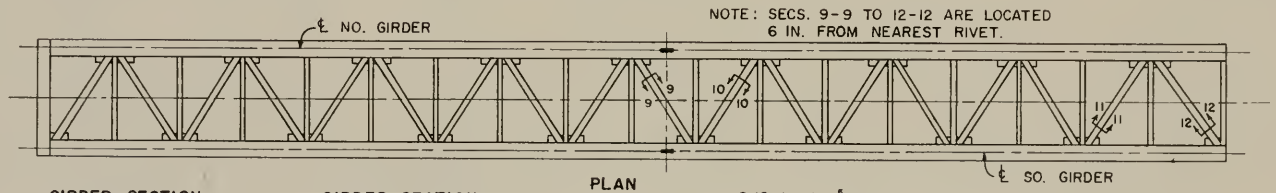
FIG. 9

C.M.ST.P & P. RR. BRIDGE TESTS
40'-0 & 55'-0 DECK GIRDER SPANS
OPEN TIMBER FLOOR

LOCATION OF GAGES

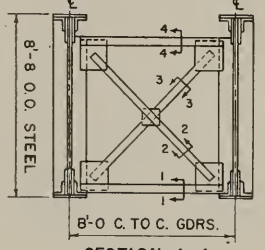


ELEVATION



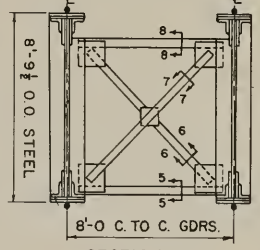
PLAN

GIRDER SECTION:
1 WEB 102 x ⅝
4 L 8 x 8 x 1
4 SIDE PLS 15½ x ½
2 COV. PLS 20 x ¾

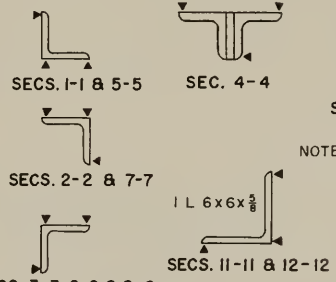


SECTION A-A
END CROSS FRAME

GIRDER SECTION:
1 WEB 102 x ⅝
4 L 8 x 8" x 1
4 SIDE PLS 15½ x ½
4 COV. PLS 20 x ¾



SECTION B-B
CENTER CROSS FRAME



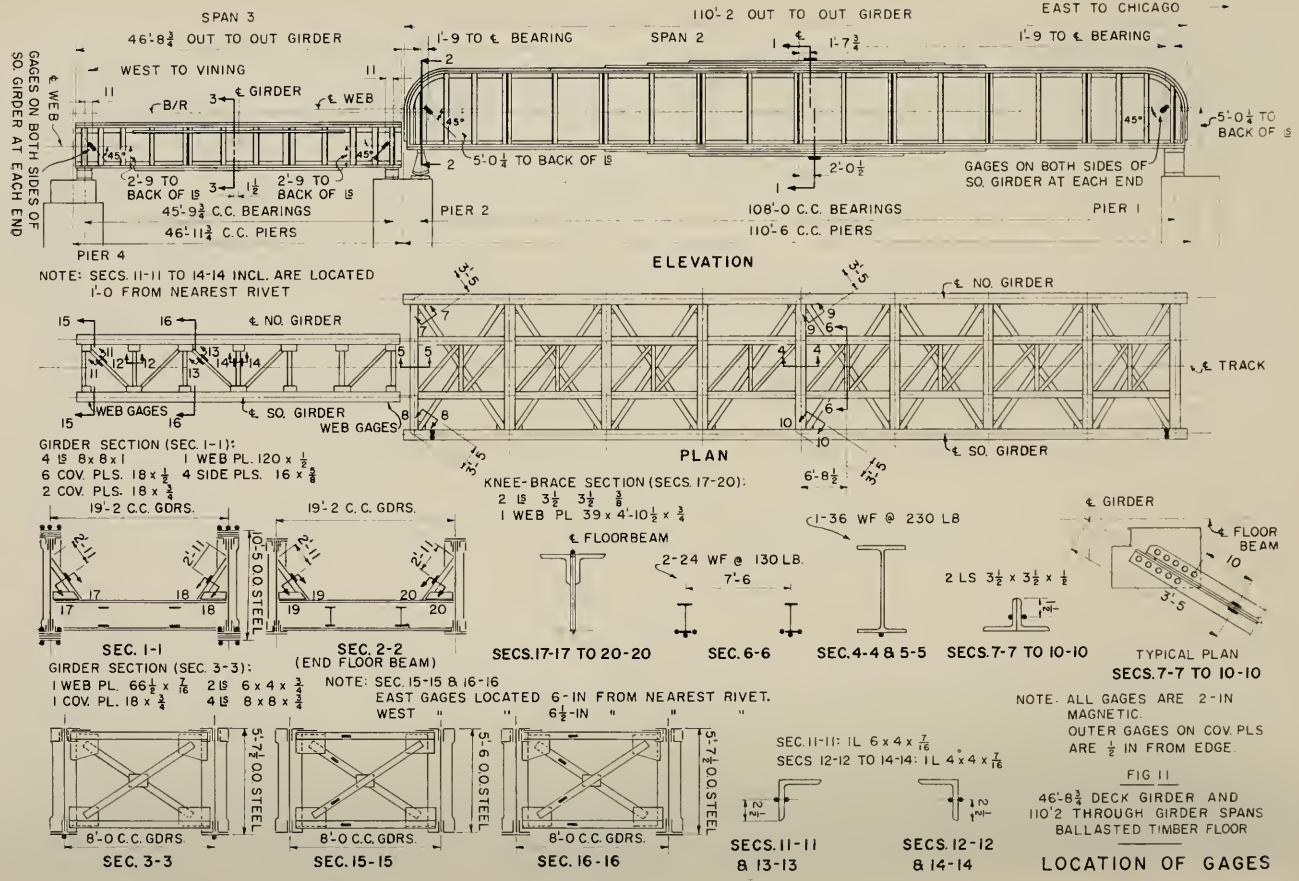
SYMBOL: ▼½ IN. SR4 WIRE GAGE
●2 IN. MAGNETIC GAGE
↗1 IN. SR4 WIRE ROSETTE GAGE.

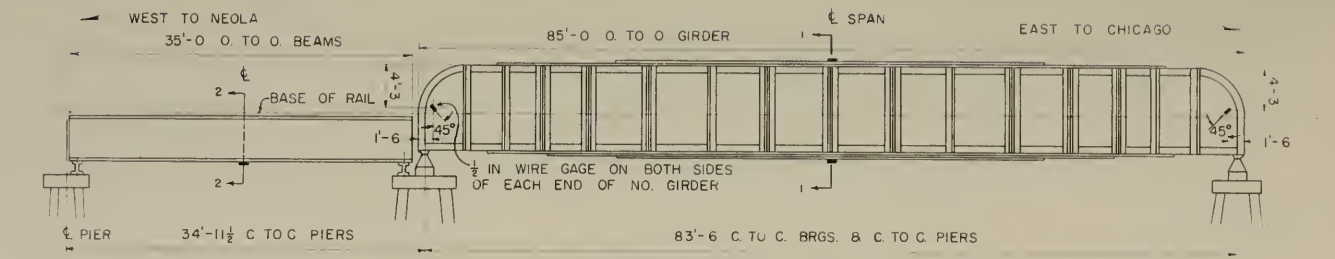
NOTE: SECS. 1-1, 2-2, 3-3, 6-6 & 7-7
1 L 4 x 4 x ⅝
SEC. 5-5, 8-8
1 L 4 x 4 x ½

NOTE: ALL GAGES ARE ¼ IN FROM NEAREST EDGE.

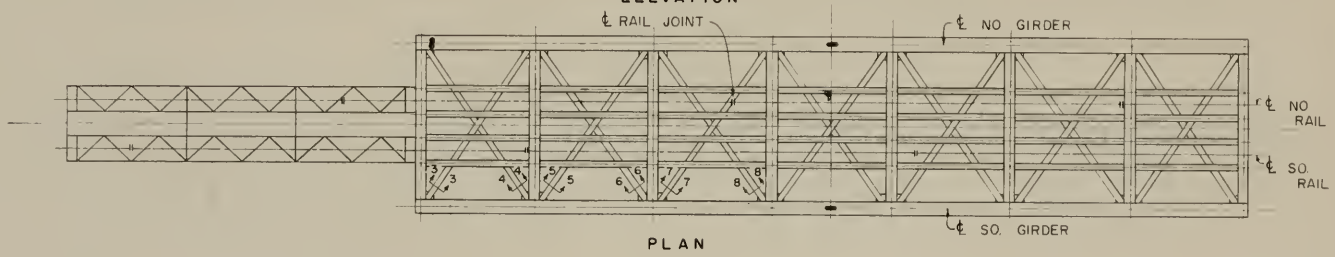
FIG. 10
C.M.ST.P & P. RR. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR

LOCATION OF GAGES

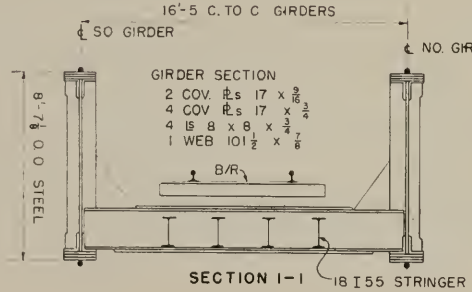

SPAN 3
46'-8¾ OUT TO OUT GIRDER
WEST TO VINING
GAGES ON BOTH SIDES OF SO. GIRDER AT EACH END
℄ WEB
B/R
℄ GIRDER
℄ WEB
2'-9 TO BACK OF ℒS
2'-9 TO BACK OF ℒS
45°-9¾ C.C. BEARINGS
46'-11¾ C.C. PIERS
PIER 4
PIER 2
1'-9 TO ℄ BEARING
5'-0¼ TO BACK OF ℒS
110'-2 OUT TO OUT GIRDER
SPAN 2
1'-7¾
2'-0½
108'-0 C.C. BEARINGS
110'-6 C.C. PIERS
PIER 1
EAST TO CHICAGO
1'-9 TO ℄ BEARING
5'-0¼ TO BACK OF ℒS
GAGES ON BOTH SIDES OF SO. GIRDER AT EACH END
ELEVATION
NOTE: SECS. 11-11 TO 14-14 INCL. ARE LOCATED 1'-0 FROM NEAREST RIVET
℄ NO. GIRDER
℄ TRACK
WEB GAGES
℄ SO. GIRDER
WEB GAGES
℄ SO. GIRDER
PLAN
GIRDER SECTION (SEC. 1-1):
4 ℒS 8 x 8 x 1
6 COV. PLS. 18 x ½
2 COV. PLS. 18 x ¾
1 WEB PL. 120 x ½
4 SIDE PLS. 16 x ⅜
KNEE-BRACE SECTION (SECS. 17-20):
2 ℒS 3½ 3½ ⅜
1 WEB PL 39 x 4'-10½ x ¾
19'-2 C.C. GDRS.
10'-5.00 STEEL
SEC. 1-1
19'-2 C. C. GDRS.
SEC. 2-2
(END FLOOR BEAM)
℄ FLOORBEAM
SECS. 17-17 TO 20-20
2-24 WF @ 130 LB.
7'-6
SEC. 6-6
1-36 WF @ 230 LB
SEC. 4-4 & 5-5
2 LS 3½ x 3½ x ½
SECS. 7-7 TO 10-10
℄ GIRDER
℄ FLOOR BEAM
10
3'-5
TYPICAL PLAN
SECS. 7-7 TO 10-10
GIRDER SECTION (SEC. 3-3):
1 WEB PL. 66½ x 7/16
1 COV. PL. 18 x ¾
2 ℒS 6 x 4 x 7/16
4 ℒS 8 x 8 x 1
NOTE: SEC. 15-15 & 16-16
EAST GAGES LOCATED 6-IN FROM NEAREST RIVET.
WEST " " 6½-IN " " "
5'-7.00 STEEL
8'-0 C.C. GDRS.
SEC. 3-3
5'-6.00 STEEL
8'-0 C.C. GDRS.
SEC. 15-15
5'-7.00 STEEL
8'-0 C.C. GDRS.
SEC. 16-16
SEC. 11-11: 1L 6 x 4 x 7/16
SECS 12-12 TO 14-14: 1L 4 x 4 x 7/16
SECS. 11-11 & 13-13
SECS. 12-12 & 14-14
NOTE. ALL GAGES ARE 2-IN MAGNETIC.
OUTER GAGES ON COV. PLS ARE ½ IN FROM EDGE.
FIG 11
46'-8¾ DECK GIRDER AND 110'2 THROUGH GIRDER SPANS BALLASTED TIMBER FLOOR
LOCATION OF GAGES


WEST TO NEOLA
35'-0 O. TO O. BEAMS
℄ SPAN
85'-0 O. TO O GIRDER
EAST TO CHICAGO
BASE OF RAIL
4'-3"
1'-6
45°
½ IN WIRE GAGE ON BOTH SIDES OF EACH END OF NO. GIRDER
℄ PIER
34'-11½ C TO C PIERS
83'-6 C. TO C. BRGS. & C. TO C. PIERS

ELEVATION



PLAN

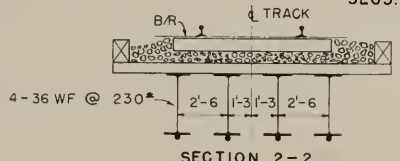

16'-5 C. TO C GIRDERS
℄ SO GIRDER
℄ NO. GIRDER
GIRDER SECTION
2 COV. PLs 17 x 9/16
4 COV PLs 17 x 3/4
4 LS 8 x 8 x 3/4
1 WEB 101½ x 7/8
B/R
8'-7⅛ O O STEEL

SECTION 1-1 18 I 55 STRINGER

NOTE : SECS 3-3 TO 8-8 INCL. LOCATED 6 INCH FROM NEAREST RIVET

SECS. 3-3 TO 8-8 INCL.

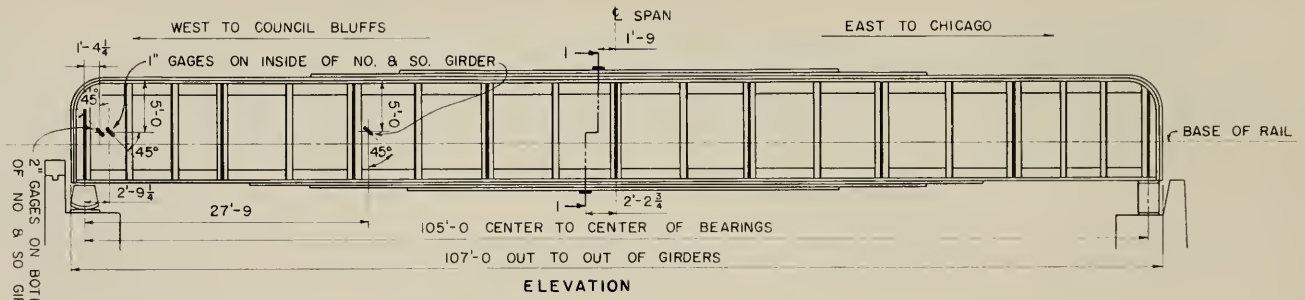
SYMBOL
▲ ½ IN WIRE GAGE
• 2 IN MAGNETIC GAGE



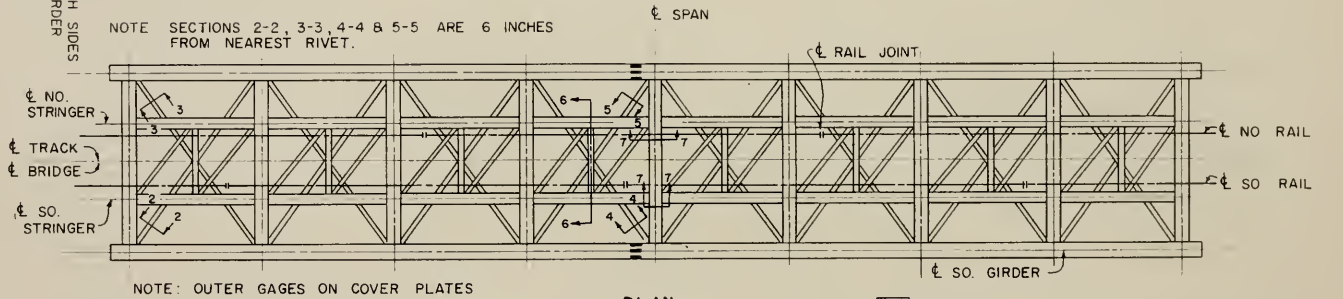
SECTION 2-2

FIG. 12
C M ST P & P R R BRIDGE TESTS
35'-0 WF BEAM AND 85'-0
THROUGH GIRDER SPANS
BALLASTED TIMBER FLOOR

LOCATION OF GAGES

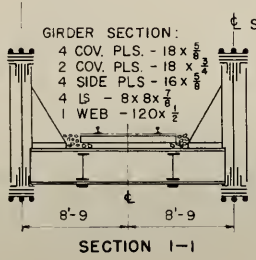


ELEVATION

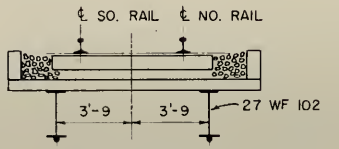


NOTE: OUTER GAGES ON COVER PLATES ARE ½ INCH FROM EDGE

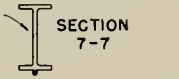
PLAN



SECTION 1-1

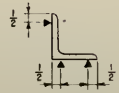


SECTION 6-6

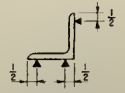


SECTION 7-7

SYMBOL:
• 2 IN. MAGNETIC GAGE
▲ 1 IN. SR-4 WIRE GAGE



SECTIONS 2-2 & 5-5



SECTIONS 3-3 & 4-4

LATERAL SECTION.
2-2 & 3-3 - 1L 4 x 4 x 1/2
4-4 & 5-5 - 1L 4 x 4 x 7/16

FIG. 13

C.M. ST. P. & P. R R BRIDGE TEST: 107'-0 THROUGH GIRDER SPAN BALLASTED TIMBER FLOOR

LOCATION OF GAGES

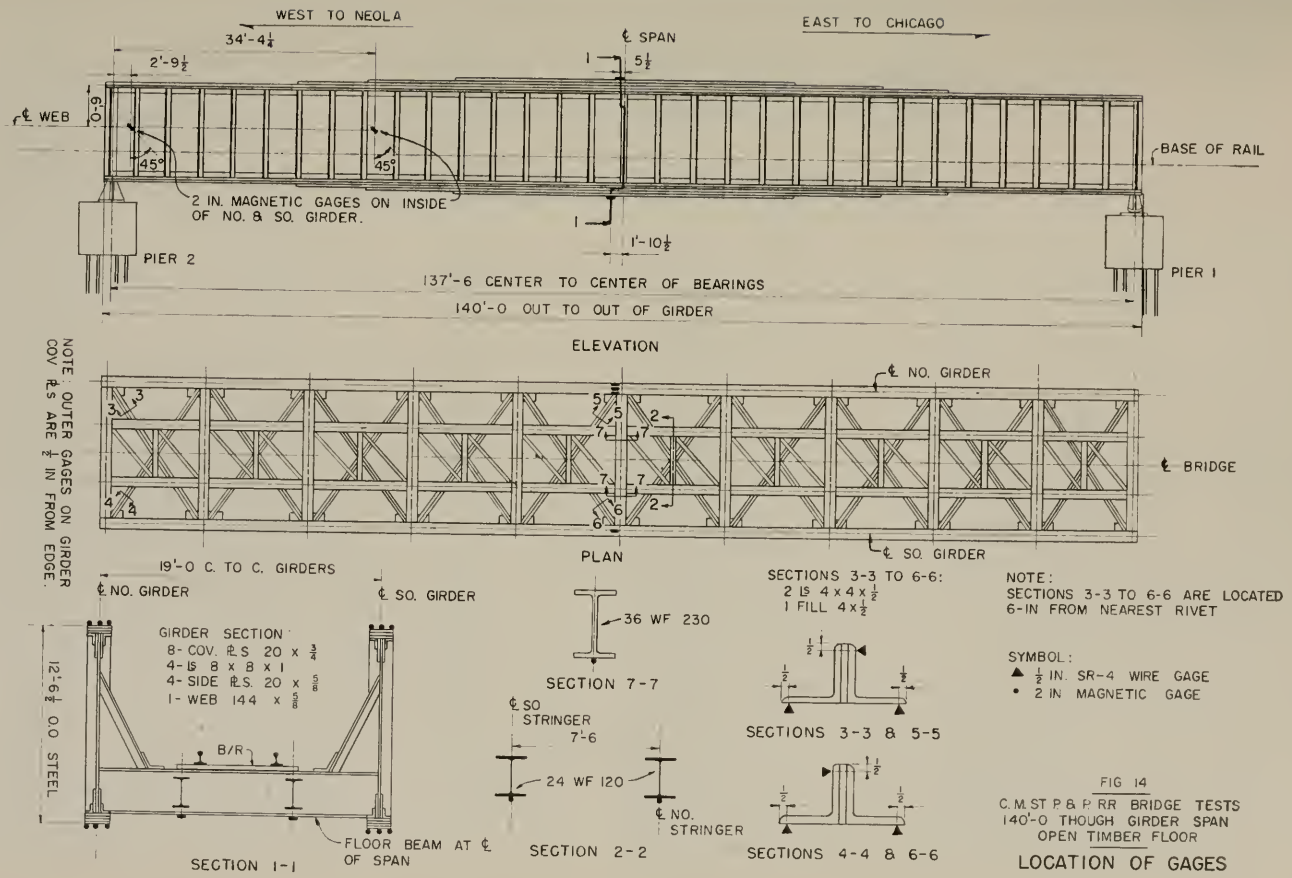


FIG 14

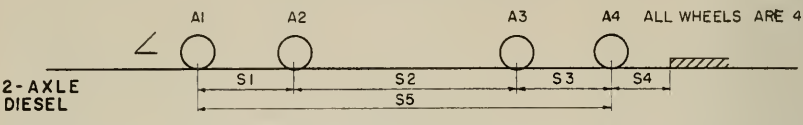
C.M.ST P & P. RR BRIDGE TESTS
140'-0 THOUGH GIRDER SPAN
OPEN TIMBER FLOOR

LOCATION OF GAGES

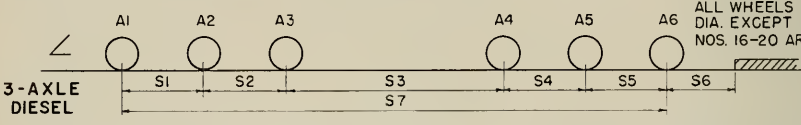
FIG 15

CHICAGO MILWAUKEE ST. PAUL & PACIFIC RAILROAD BRIDGE TESTS

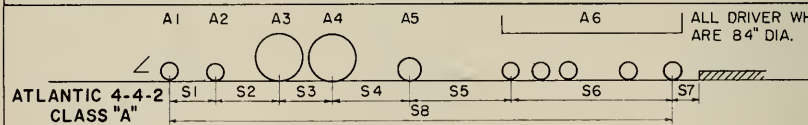
LOCOMOTIVE DATA



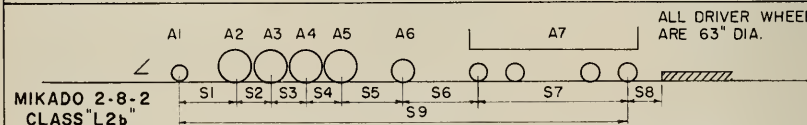
UNIT – LOCO. NOS.	AXLE WEIGHTS – KIPS				AXLE SPACINGS – FEET				
	A1	A2	A3	A4	S1	S2	S3	S4	S5
A&C 48-50, 69-79, 87-89, & 106-118	58.6	58.6	58.6	58.6	9'-0	21'-0	9'-0	5'-6	39'-0
B 48-50, 69-79, 87-89 & 106-118	57.4	57.4	57.4	57.4	9'-0	21'-0	9'-0	5'-6	39'-0
A & C 90-97	65.1	65.1	65.1	65.1	9'-0	25'-0	9'-0	5'-6	43'-0
B 90-97	62.4	62.4	62.4	62.4	9'-0	21'-0	9'-0	5'-6	39'-0



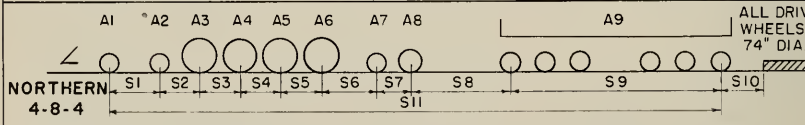
LOCO NUMBERS	AXLE WEIGHTS – KIPS						AXLE SPACINGS – FEET						
	A1	A2	A3	A4	A5	A6	S1	S2	S3	S4	S5	S6	S7
5-A, 6-A, 7-A, 8-A 10-A, 11-A, 11B, 12-A	55.9	52.6	55.9	55.9	52.6	55.9	7'-9	7'-9	20'-11	7'-9	7'-9	6'-5½	51'-11
14-A, 14-B	57.4	57.4	57.4	57.4	57.4	57.4	7'-8	7'-8	27'-8	7'-8	7'-8	7'-0	58'-4
16-20	54.6	52.8	54.6	54.6	52.8	54.8	7'-0½	7'-0½	28'-11	7'-0½	7'-0½	6'-5½	57'-1
9A, 12B, 21A&B, 22A&B	55.7	52.3	55.7	55.7	52.3	55.7	7'-9	7'-9	20'-11	7'-9	7'-9	6'-5½	51'-11
5-B, 6-B, 7-B & 8-B	56.0	52.7	56.0	56.0	52.7	56.0	7'-9	7'-9	20'-11	7'-9	7'-9	6'-5½	51'-11



LOCO. NUMBERS	AXLE WEIGHTS – KIPS						AXLE SPACINGS – FEET							
	A1	A2	A3	A4	A5	A6	S1	S2	S3	S4	S5	S6	S7	S8
1-4	36.0	36.0	71.0	71.0	72.0	277.4	7'-2	9'-11	8'-6	12'-0	16'-0½	25'-5	3'-11 3/16	78'-10½



LOCO. NUMBERS	AXLE WEIGHTS – KIPS							AXLE SPACINGS – FEET								
	A1	A2	A3	A4	A5	A6	A7	S1	S2	S3	S4	S5	S6	S7	S8	S9
400-499	24.6	55.2	55.2	55.2	55.2	47.2	193.0	9'-1	5'-6	5'-6	5'-6	9'-8	11'-9½	23'-6	5'-4 3/4	70'-6½



CLASS – LOCO. NOS	AXLE WEIGHTS – KIPS									AXLE SPACINGS – FEET									
	A1	A2	A3	A4	A5	A6	A7	A8	A9		S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
"S 2" 201-240	43.9	43.9	70.6	70.6	70.6	70.6	60.2	60.2	39.7	2.0	7'-10	6'-3	6'-5	6'-5	6'-5	8'-8	5'-4	15'-8½	33'-0	6'-9¼	96'-0½
"S 3" 260-269	43.9	43.5	64.8	64.8	64.8	64.8	56.9	56.9	36.4	2.0	7'-4	5'-9	6'-7	6'-7	6'-7	8'-5	5'-4	15'-0⅛	33'-1	6'-2⅛	95'-6⅛

NOTE UNIFORM LOAD ASSUMED TO BE { 2 KIPS PER FOOT OF TRACK FOR PASSENGER CARS; 3 KIPS PER FOOT OF TRACK FOR FREIGHT CARS

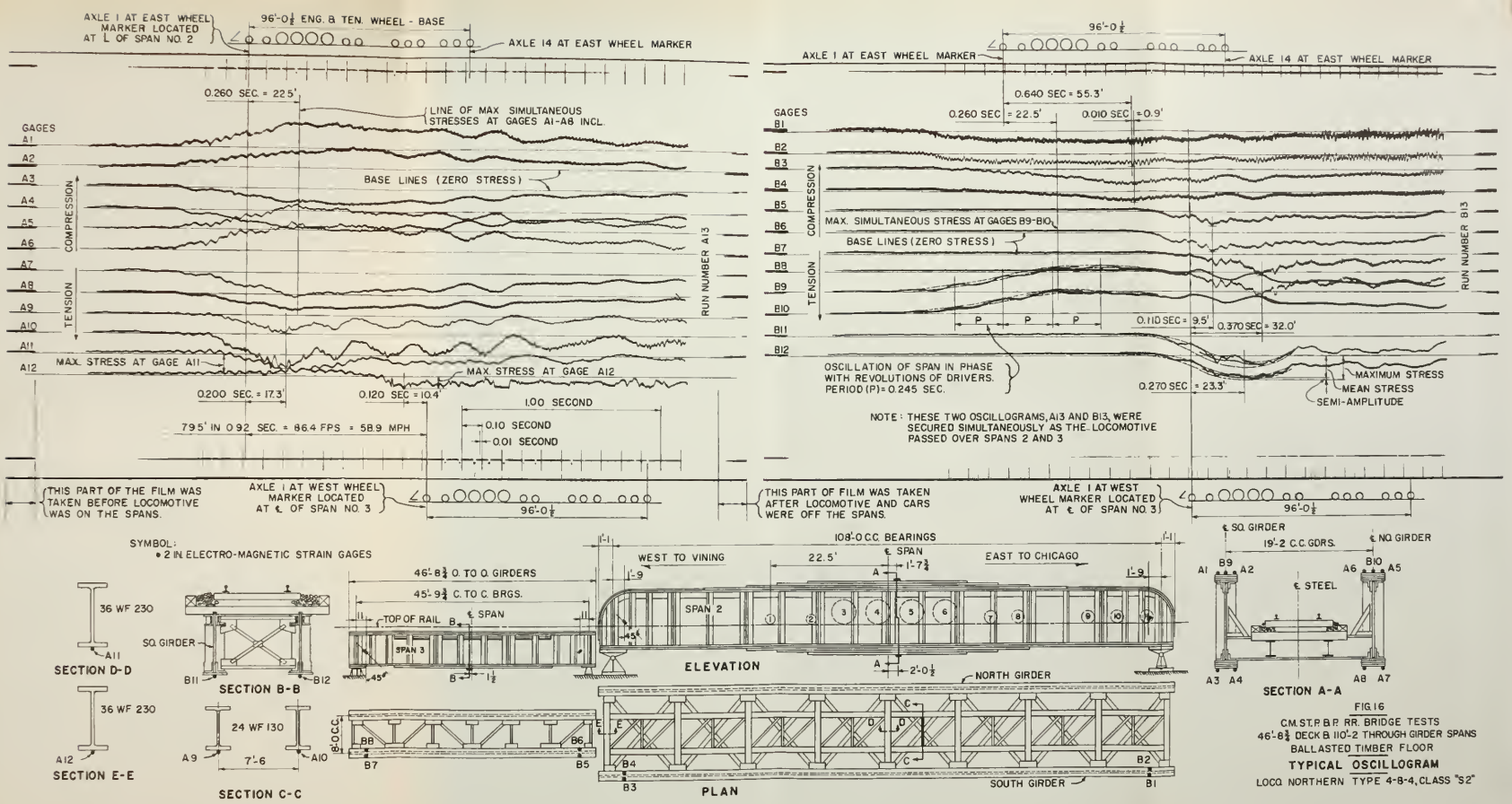


FIG. 16

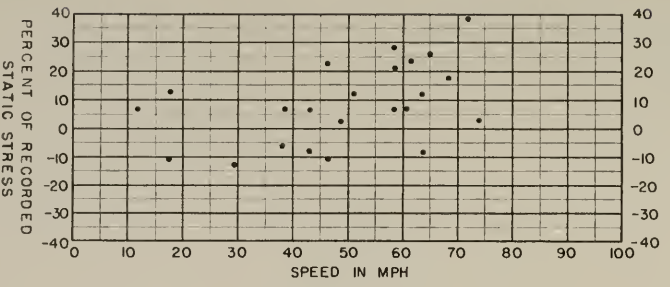
C.M.ST.P. & P. RR. BRIDGE TESTS

46'-8¾ DECK & 110'-2 THROUGH GIRDER SPANS

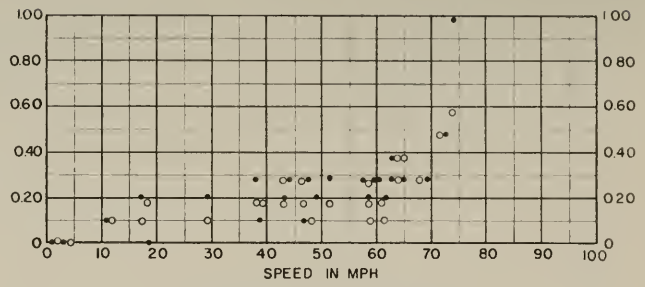
BALLASTED TIMBER FLOOR

TYPICAL OSCILLOGRAM

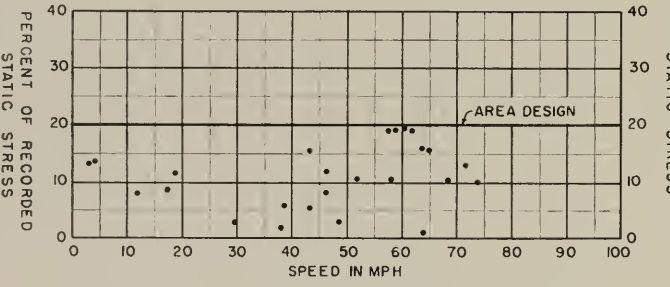
LOCO. NORTHERN TYPE 4-8-4, CLASS "S2"



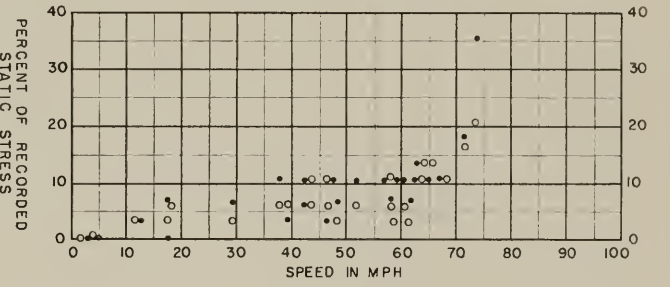
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)

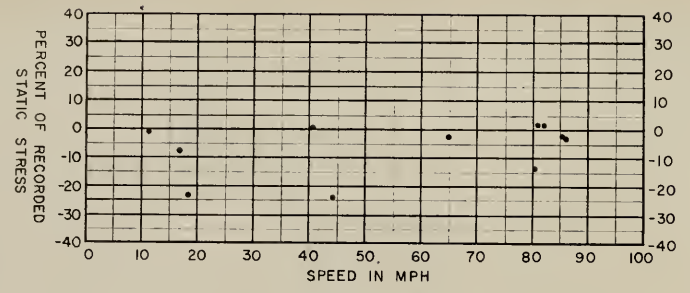


TRACK EFFECT

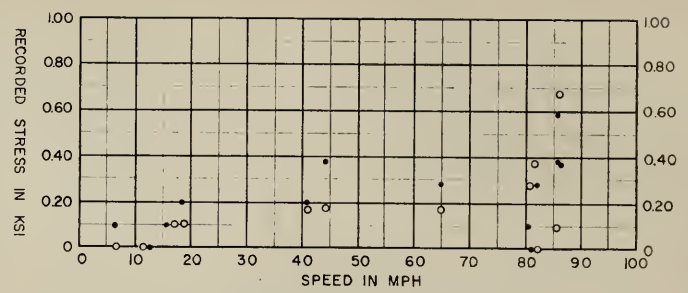
SYMBOL: o NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 11.18 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

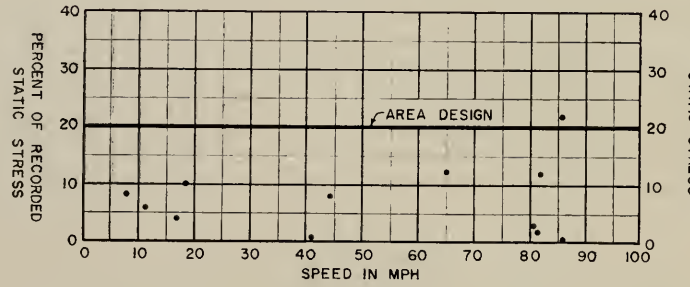
FIG. 17
C.M. ST.P. & P.R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER-EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2-AXLE DIESELS



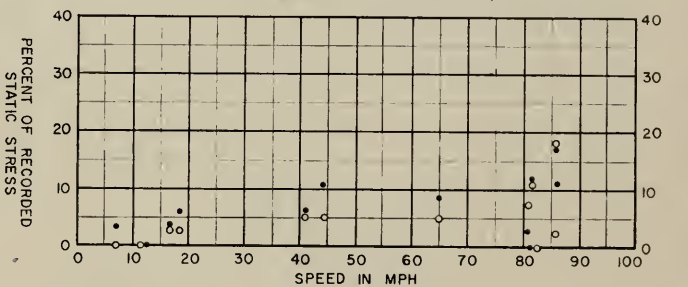
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 10.10 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

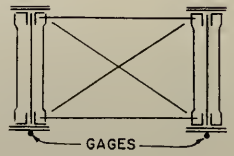


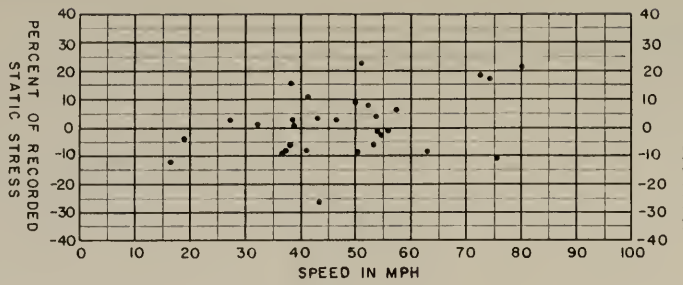
FIG. 18

C.M. ST. P. & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR

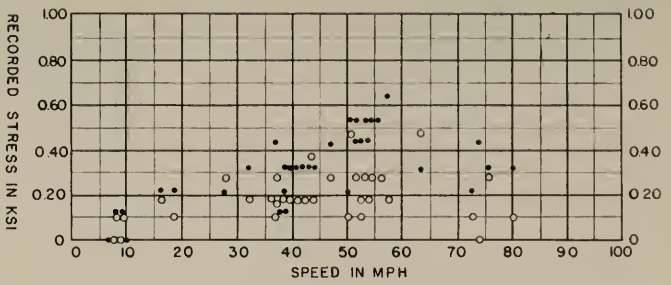
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK EFFECTS

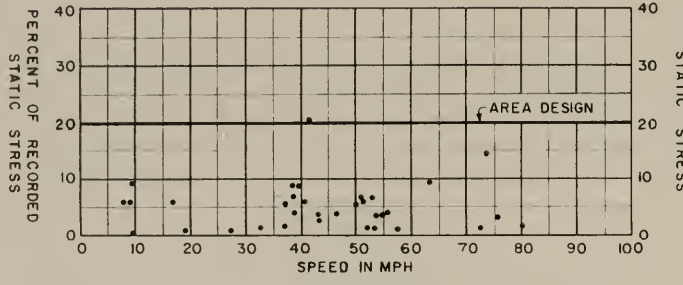
3-AXLE DIESELS



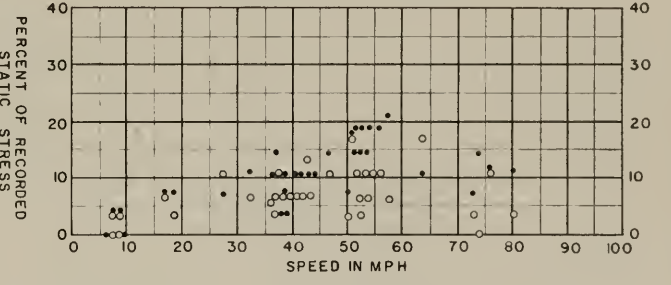
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 11.18 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

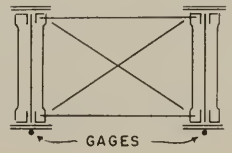
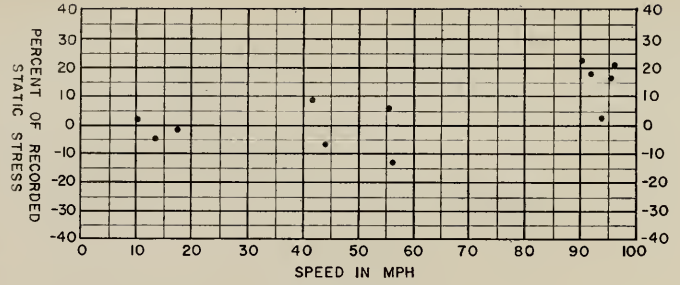
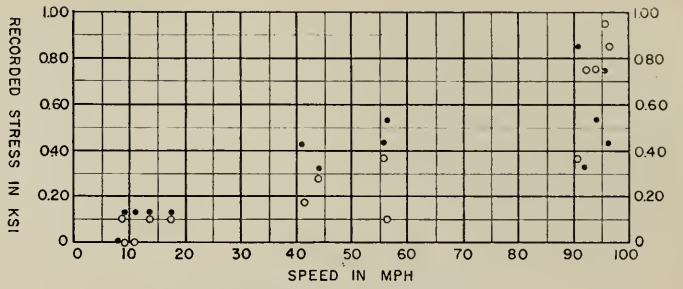


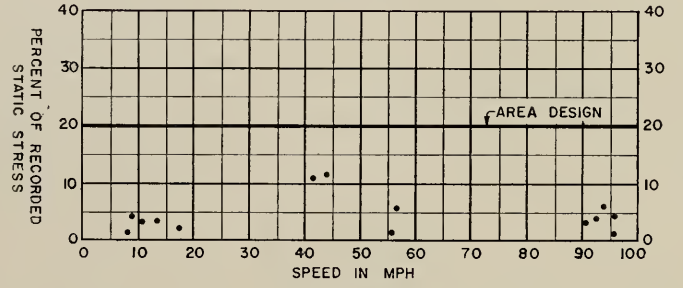
FIG. 19
C.M. ST.P&P RR BRIDGE TESTS
40'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2-AXLE DIESELS



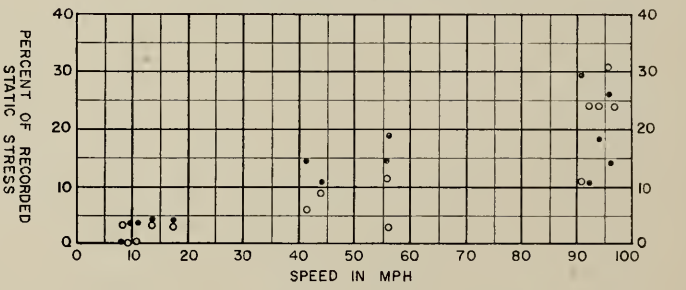
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: o NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n"= 10.88 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

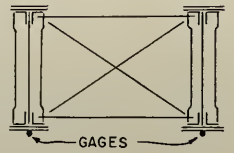


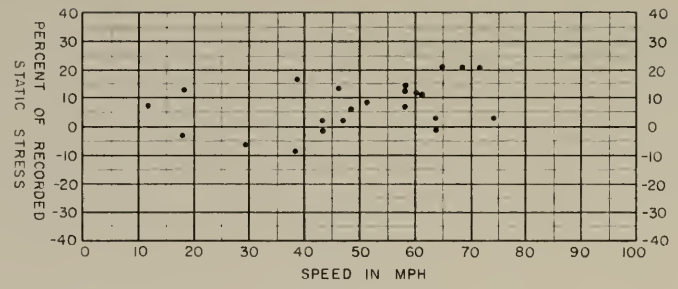
FIG.20

C.M. ST. P & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - WESTBOUND SPAN
OPEN TIMBER FLOOR

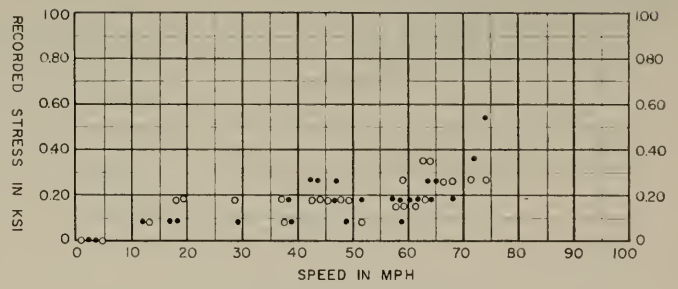
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK EFFECTS

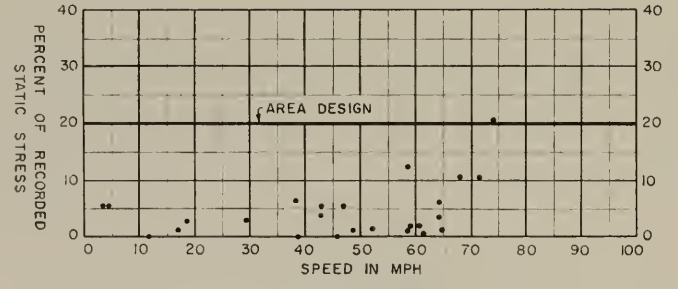
3-AXLE DIESELS



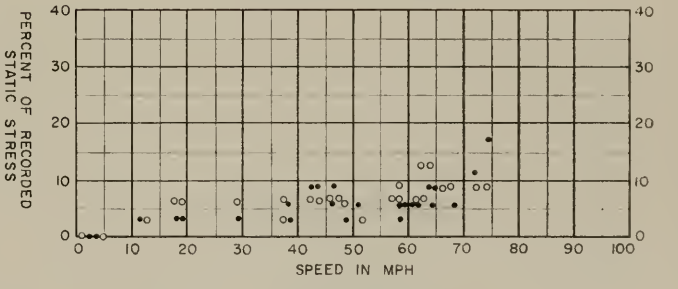
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: o NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 852 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

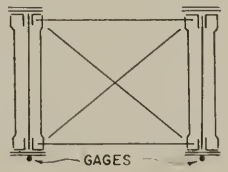
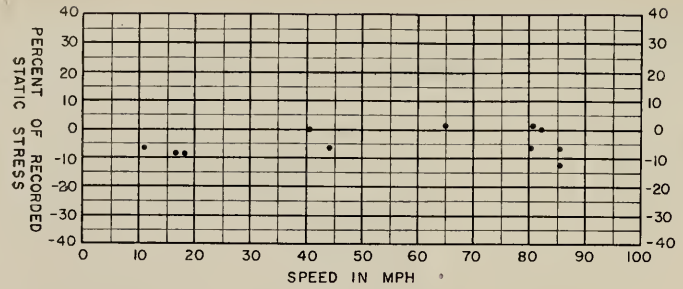


FIG. 21

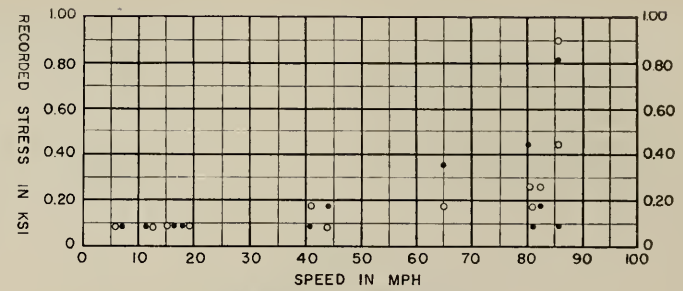
C.M. ST. P & P RR. BRIDGE TESTS
55'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK EFFECTS

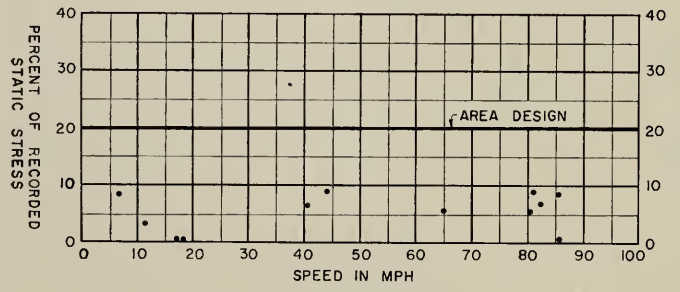
2 - AXLE DIESELS



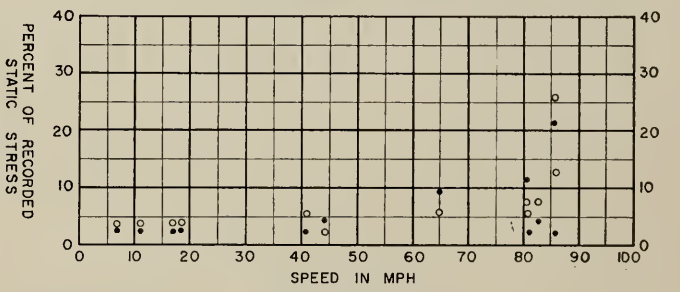
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 7.90 VPS
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

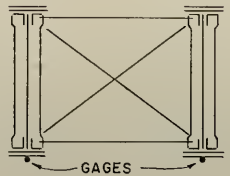


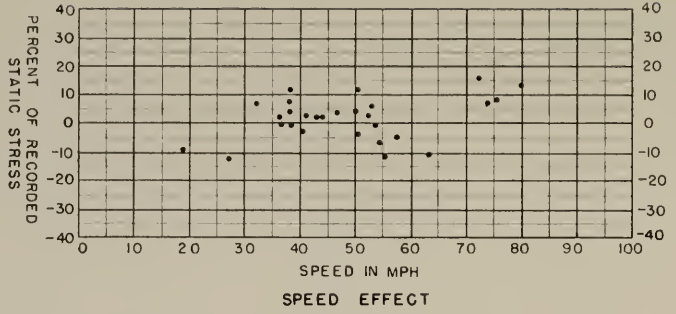
FIG. 22

C.M. ST. P. & P. R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR

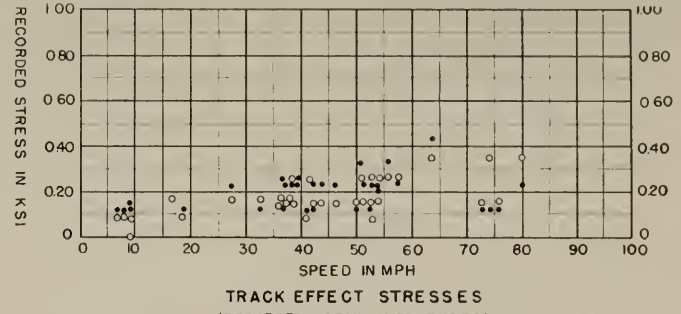
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK EFFECTS

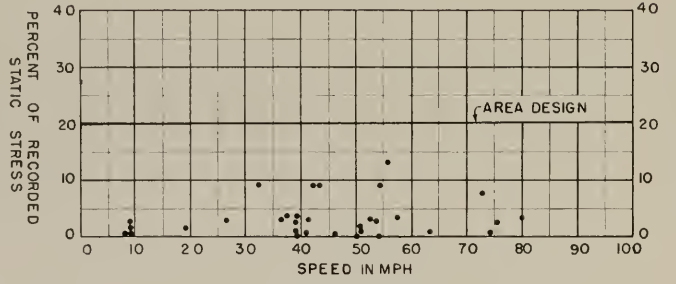
3-AXLE DIESELS



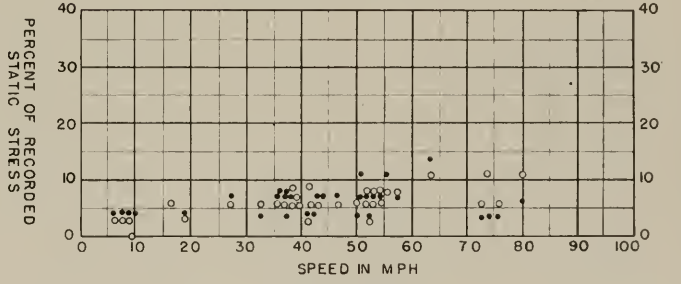
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOLS: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE · "n" = 8.30 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

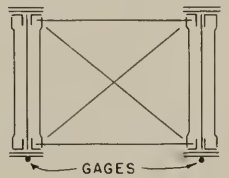
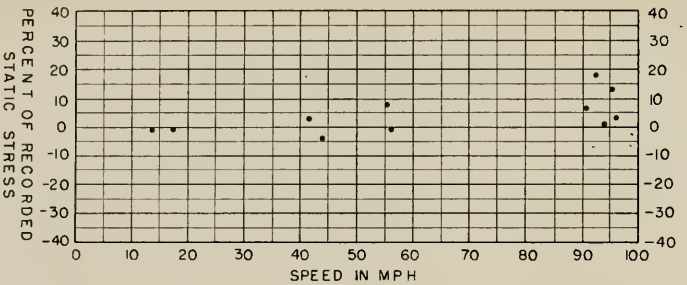


FIG. 23

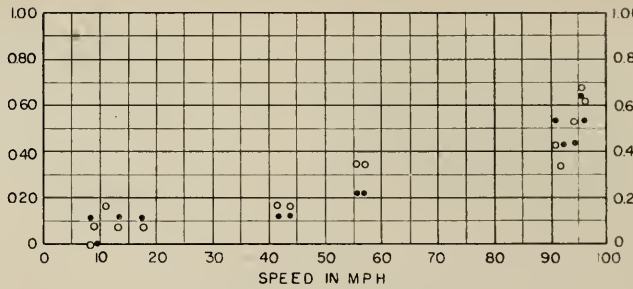
C.M. ST. P. & P. R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK EFFECTS

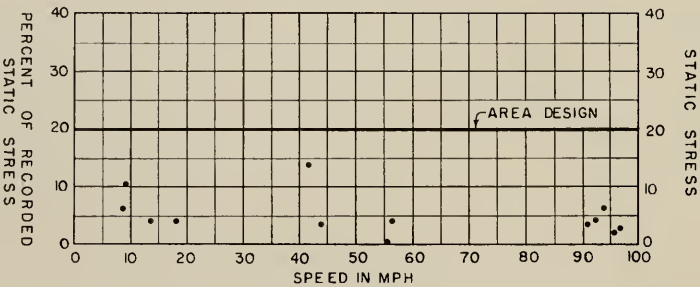
2-AXLE DIESELS



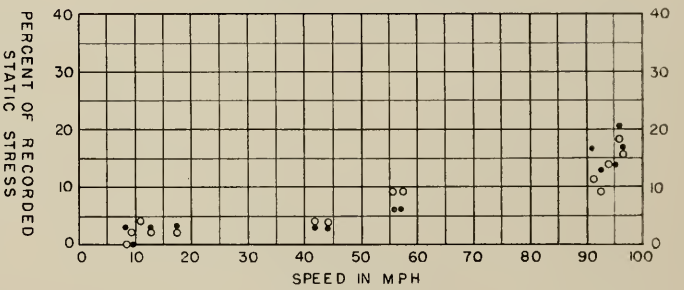
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: o NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT ROLL EFFECT

NOTE "n" = 8.02 VPS
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

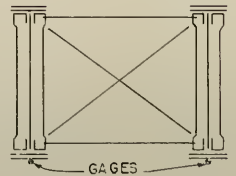
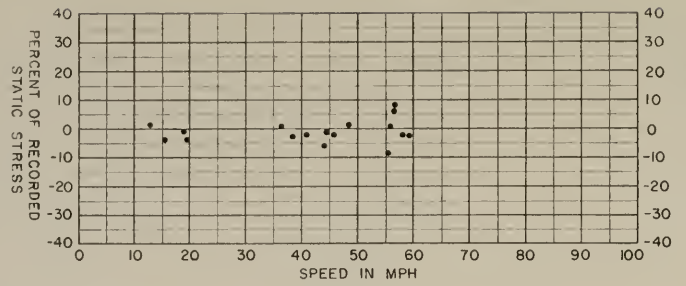
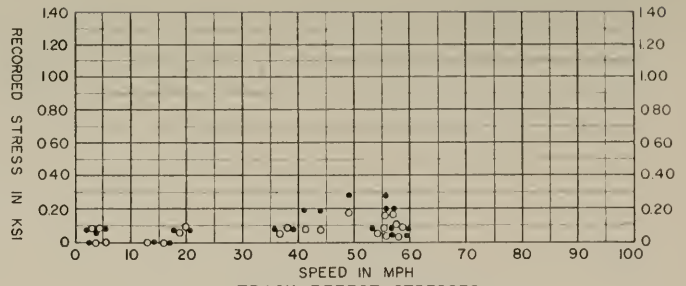


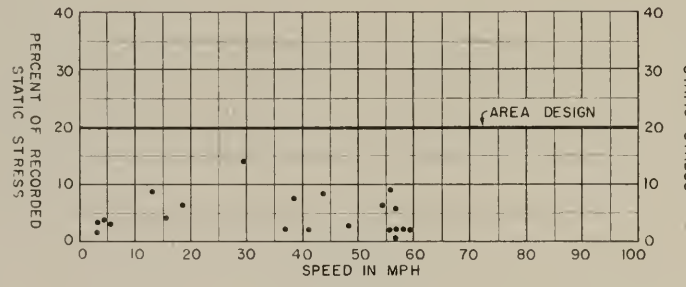
FIG. 24
C.M ST P & P RR BRIDGE TESTS
55'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
3-AXLE DIESELS



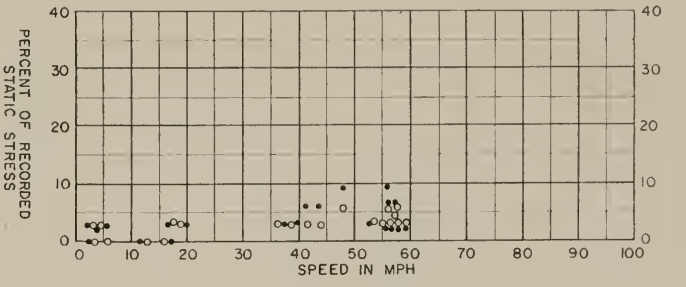
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL o NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT ROLL EFFECT

NOTE "n" = 5.61 VPS
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

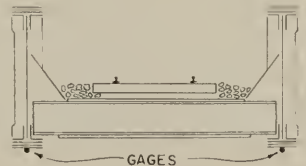
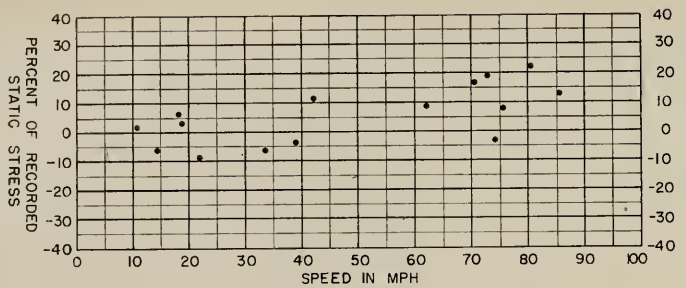
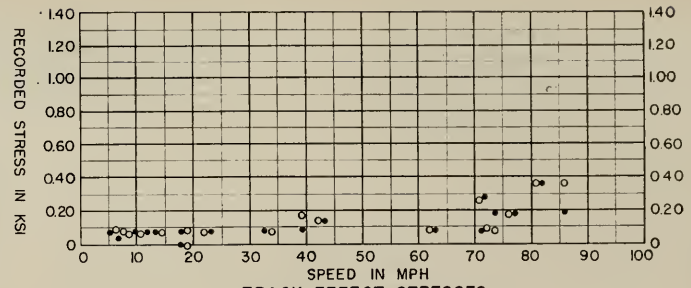


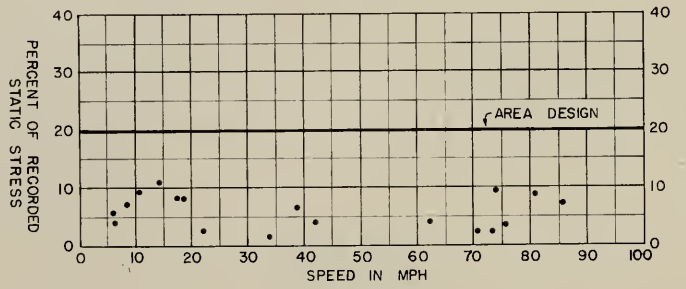
FIG. 25
C M. ST P & P R.R BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2 - AXLE DIESELS



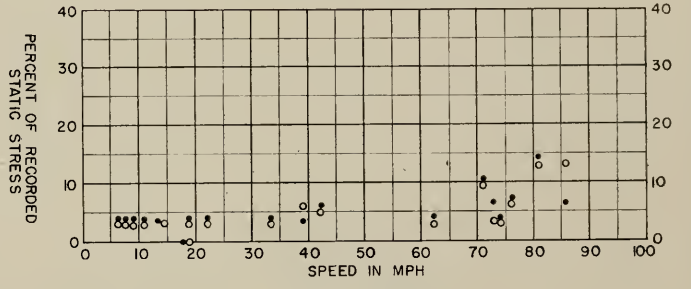
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: o NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 5.78 VPS
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

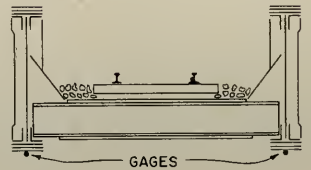
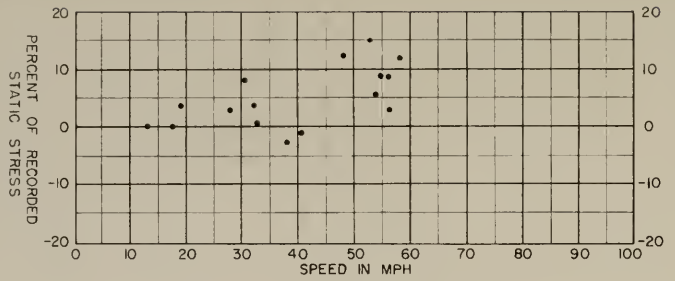
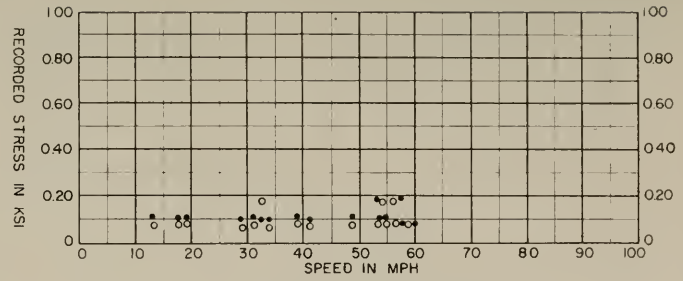


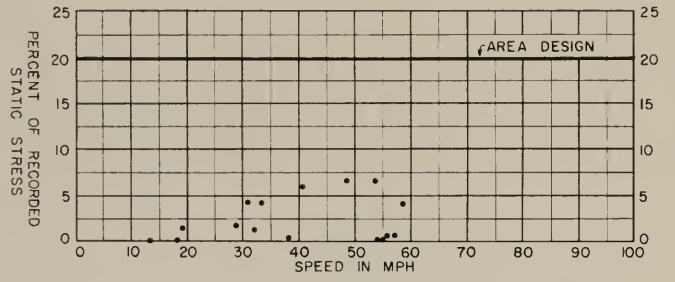
FIG. 26
C.M. ST. P. & P. R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
3 - AXLE DIESELS



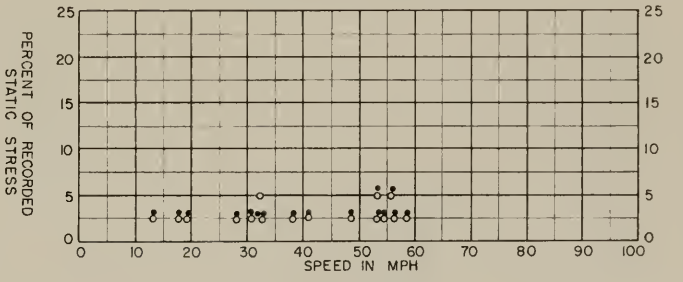
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE "n" = 5.24 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

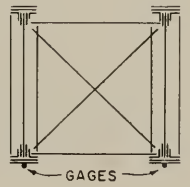
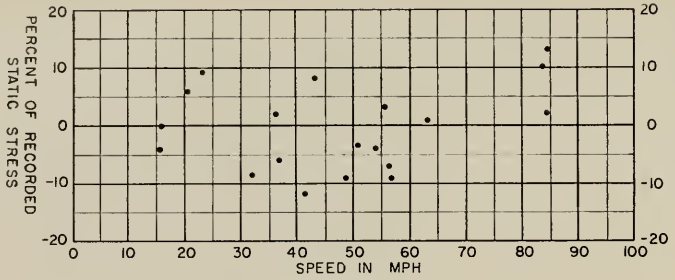
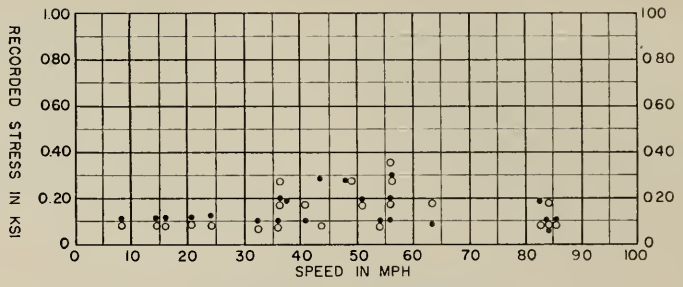


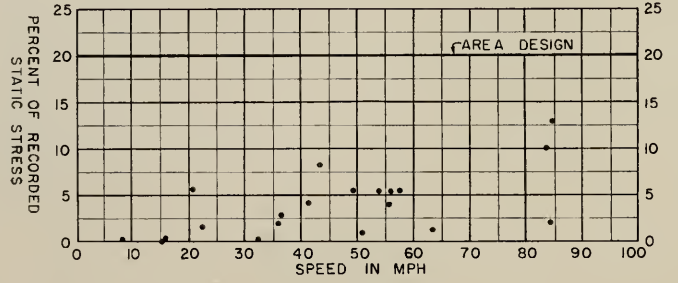
FIG. 27
C.M. ST. P. & P. R.R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2-AXLE DIESELS



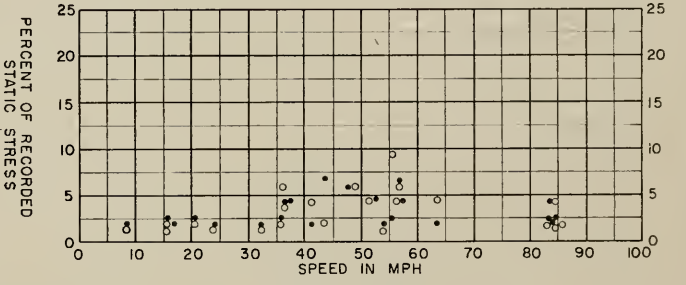
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE "n" = 475 VPS
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

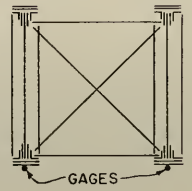
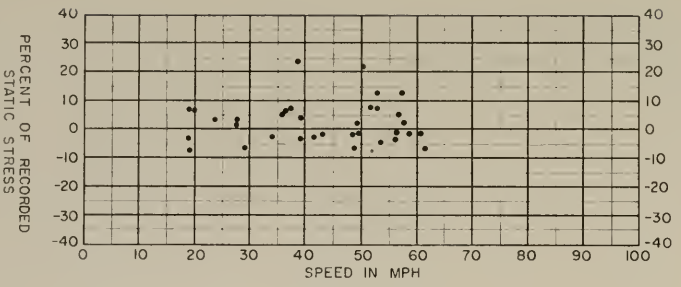
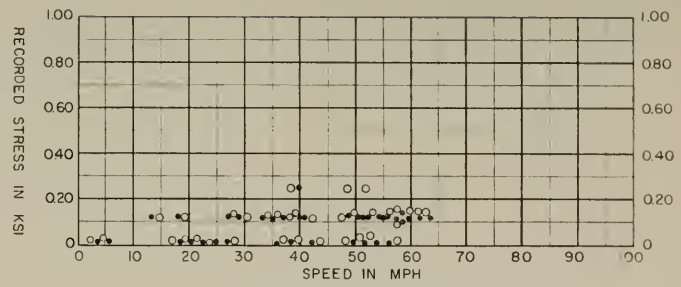


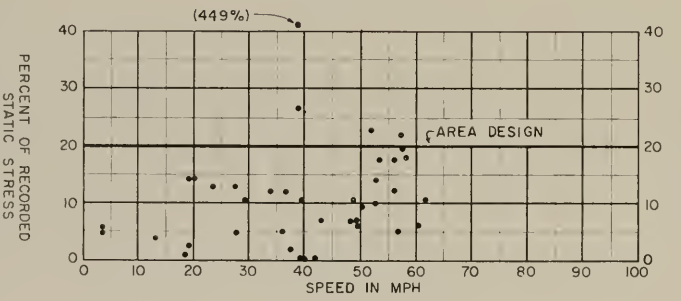
FIG. 28
C.M. ST. P & P. R.R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
3-AXLE DIESELS



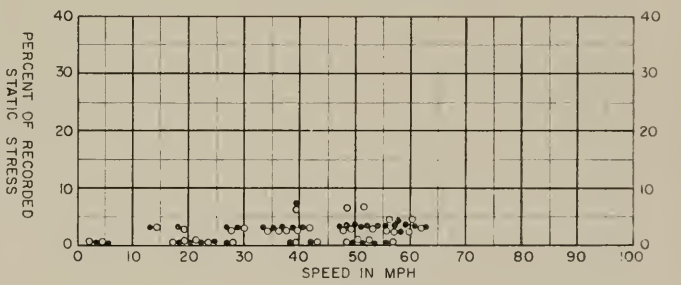
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE. "n" = 437 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

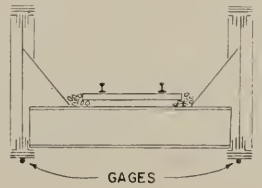
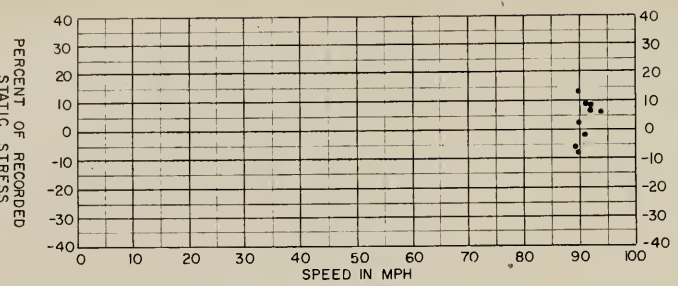
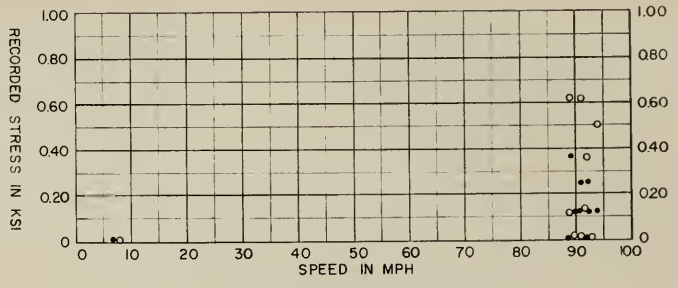


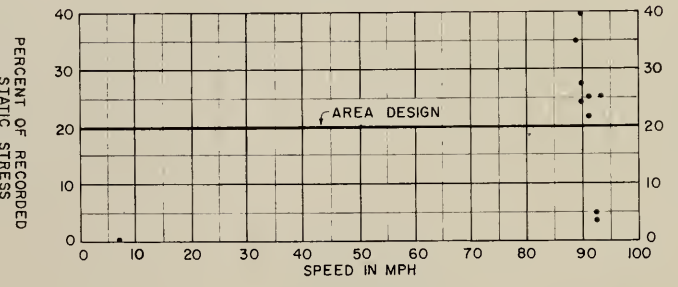
FIG 29
C. M. ST. P. & P. R. R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2- AXLE DIESELS



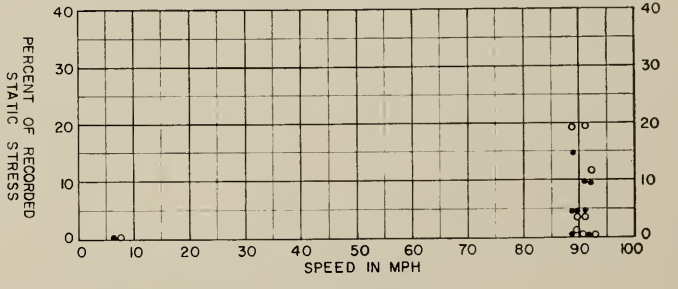
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 4.58 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

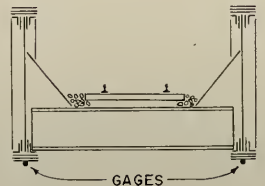
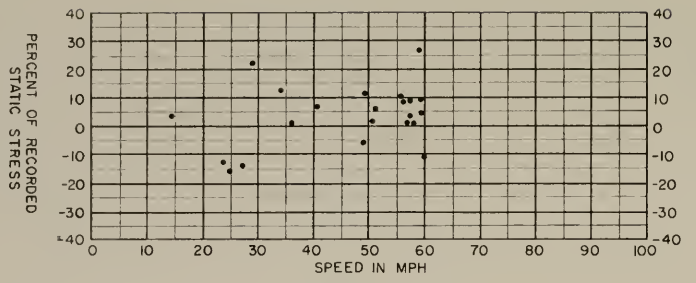
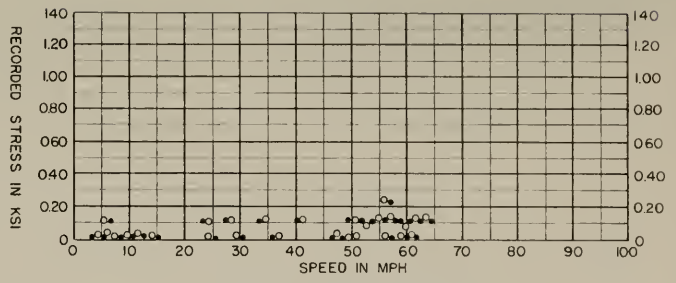


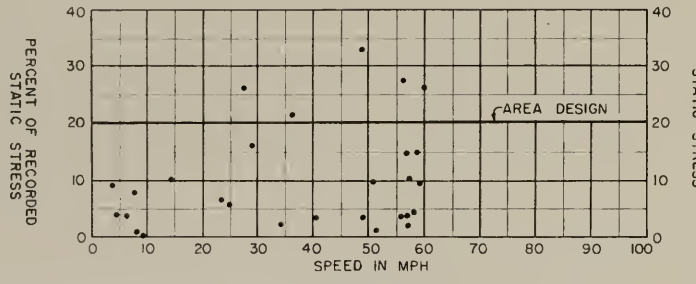
FIG. 30
C.M. ST. P. & P. R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
3 - AXLE DIESELS



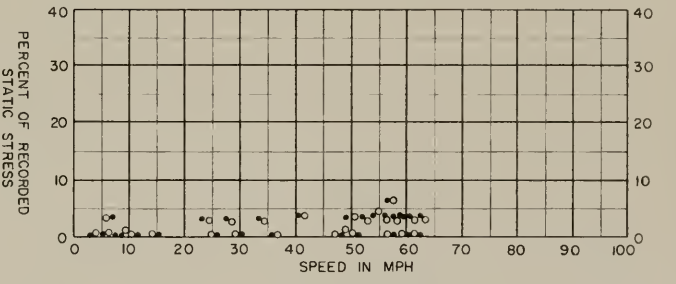
SPEED EFFECT



TRACK EFFECT STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE "n" = 3.77 VPS
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

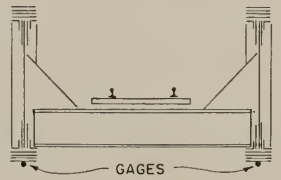
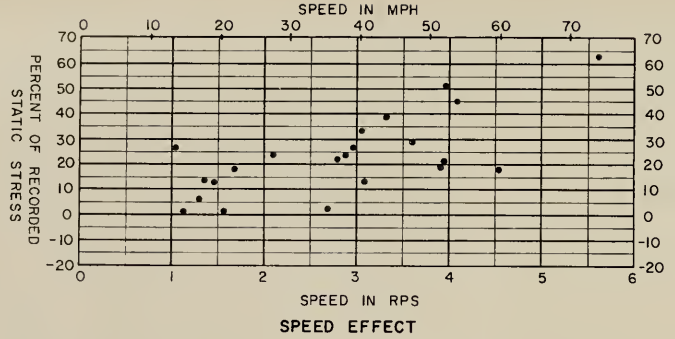
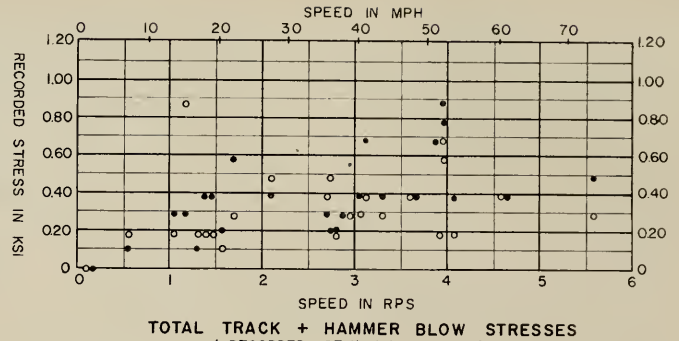


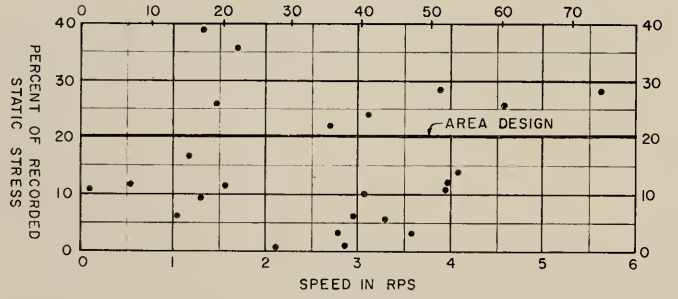
FIG. 31
C.M. ST. P & P R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK EFFECTS
2-AXLE DIESELS



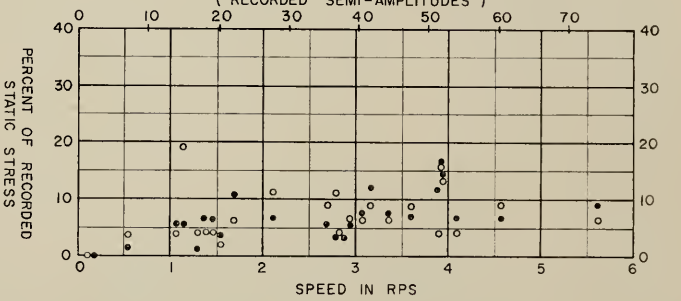
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 8.77 VPS = 115.8 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

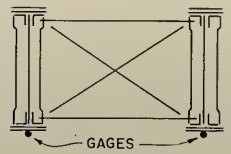
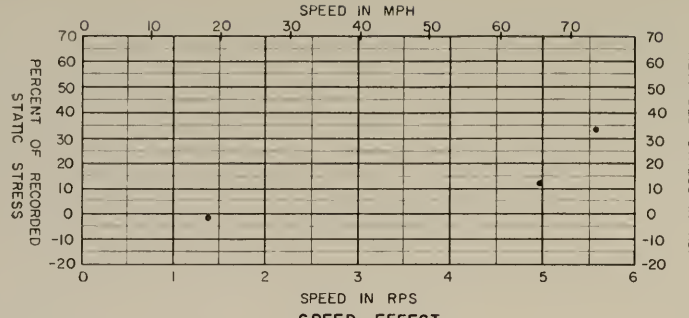
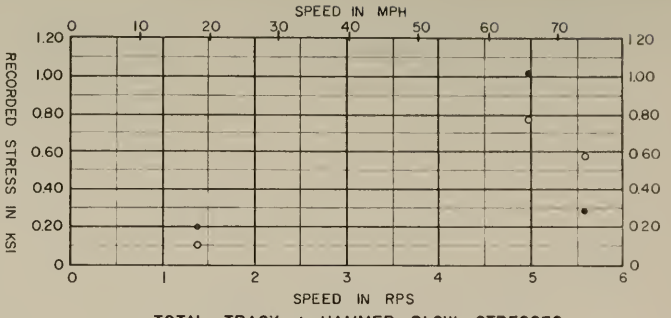


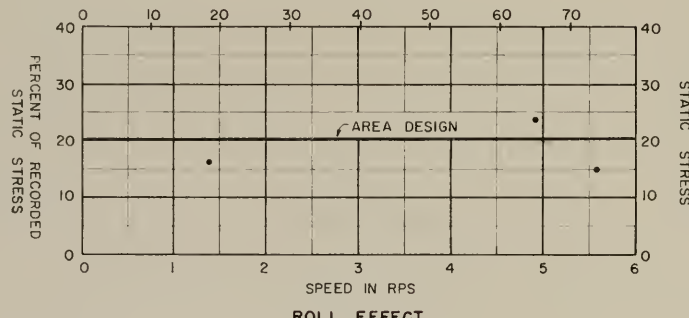
FIG. 32
C. M. ST. P. & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



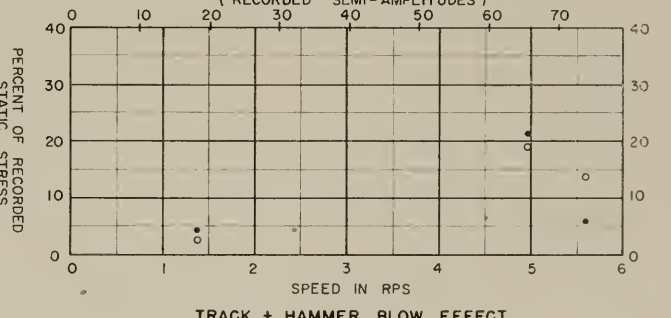
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)

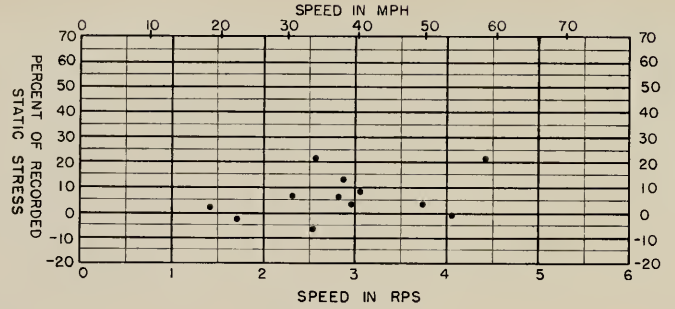


TRACK + HAMMER BLOW EFFECT

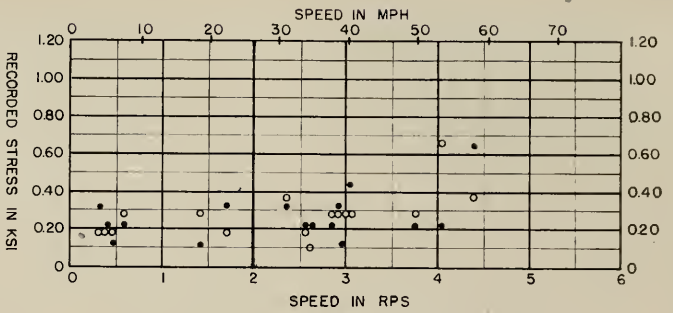
SYMBOL: o NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 9.15 VPS = 120.8 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

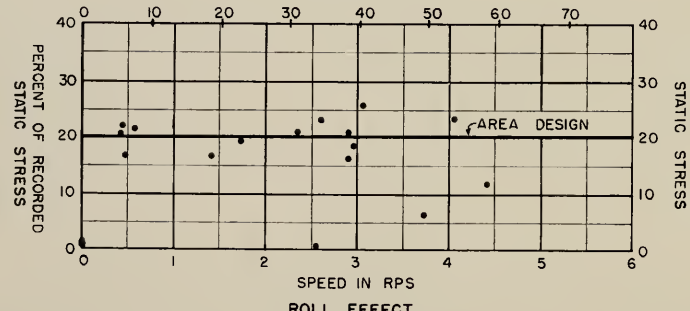
FIG 33
C.M. ST. P & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S3"



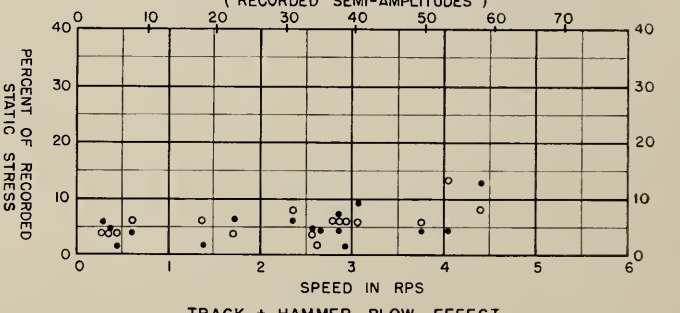
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: o NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 8.78 VPS = 116.0 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

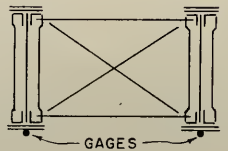
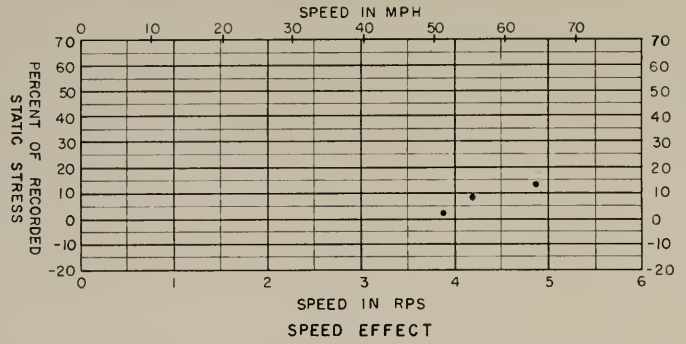
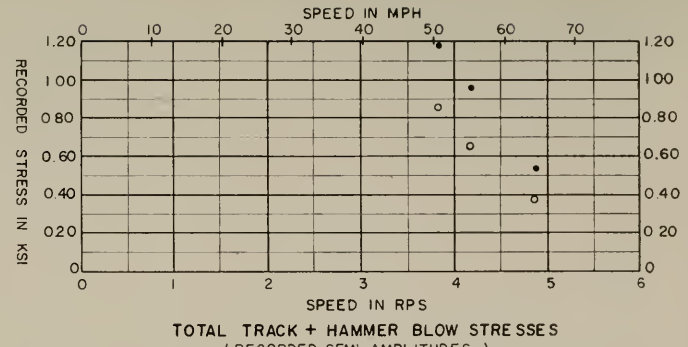


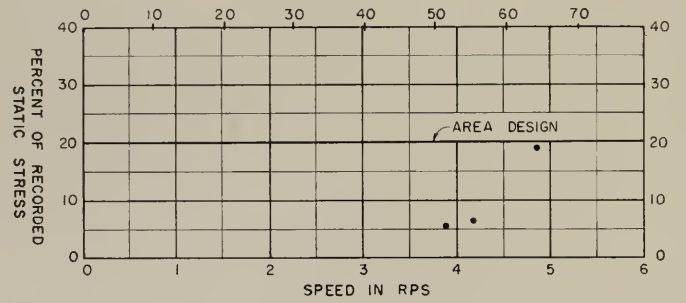
FIG. 34
C. M. ST. P & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



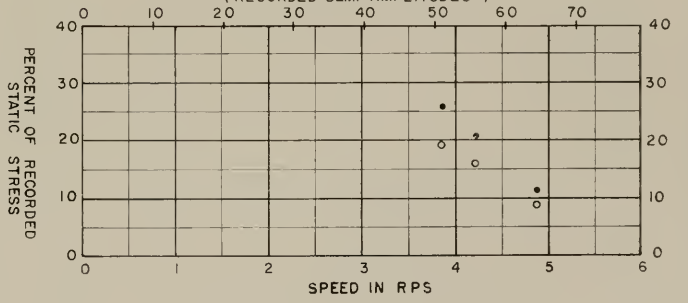
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTES: "n" = 9.15 V PS = 120.8 MPH
SEE FIG.15 FOR LOCOMOTIVE DIAGRAM

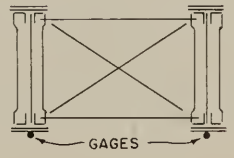
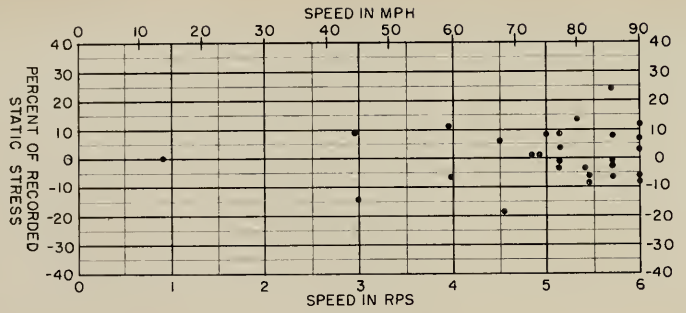


FIG.35

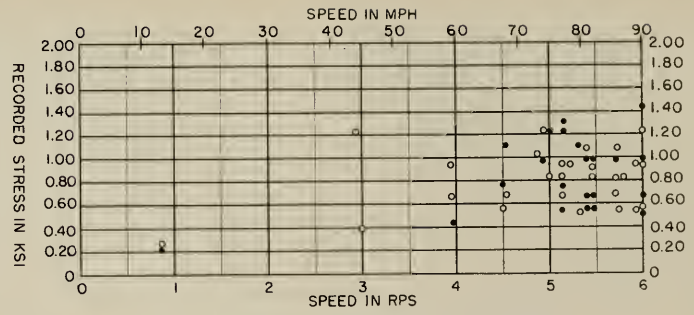
C.M. ST.P. & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS

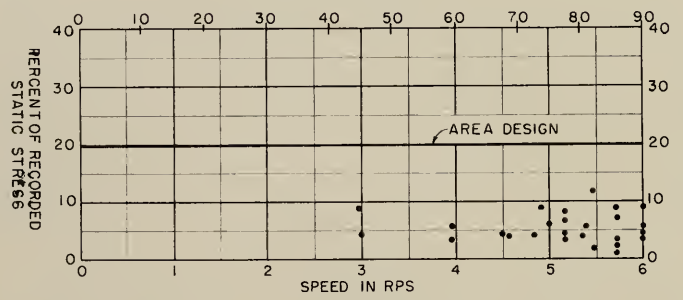
NORTHERN 4-8-4, CLASS "S3"



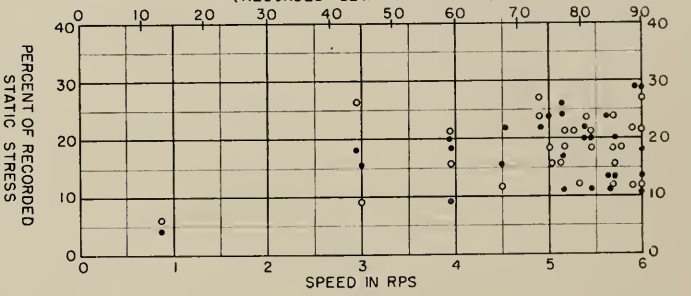
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE "n" = 7.19 VPS = 107.5 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

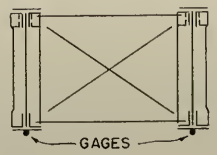
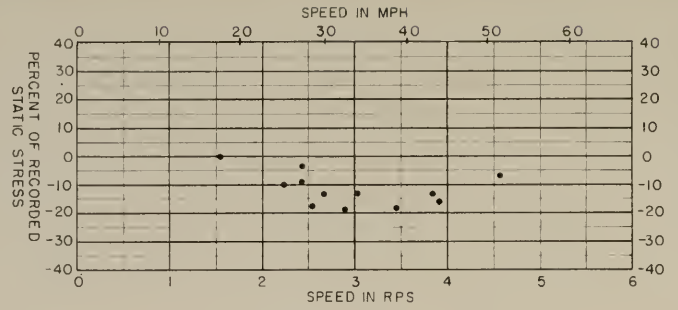
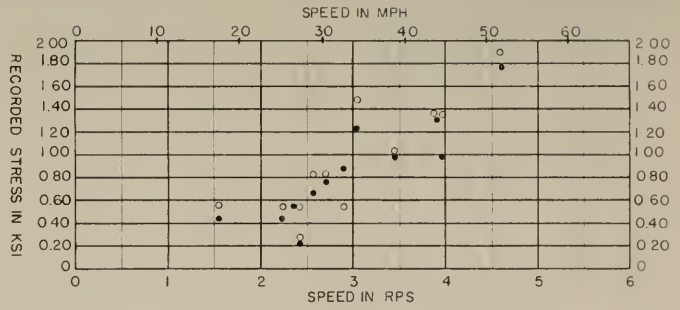


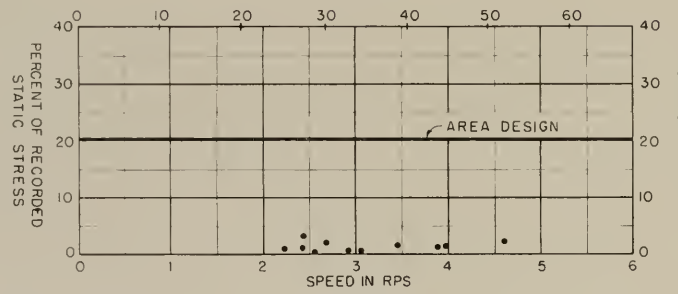
FIG. 36
C.M. ST P. & P.R.R. BRIDGE TESTS
46'-8¾ DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
ATLANTIC 4—4—2, CLASS "A"



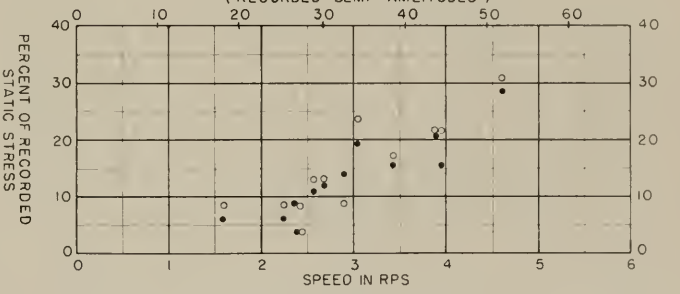
SPEED EFFECT



TOTAL TRACK+ HAMMER BLOW STRESSES
(RECORDED SEMI- AMLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)

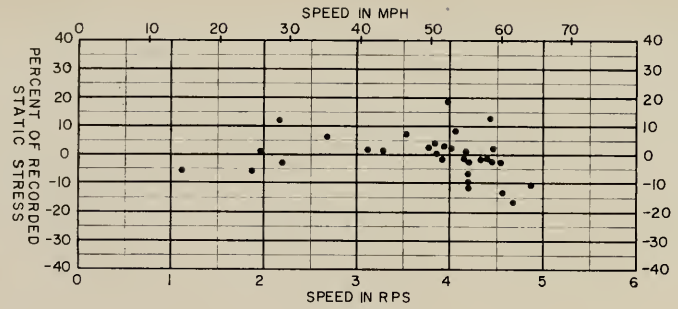


TRACK+ HAMMER BLOW EFFECT

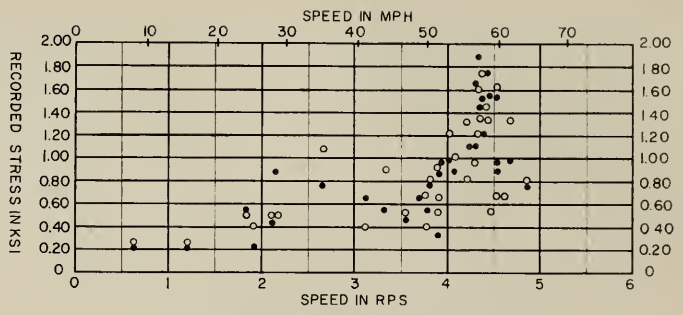
SYMBOL : o NORTH GIRDER } TRACK+ HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE : "n" = 6.52 VPS = 73.5 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

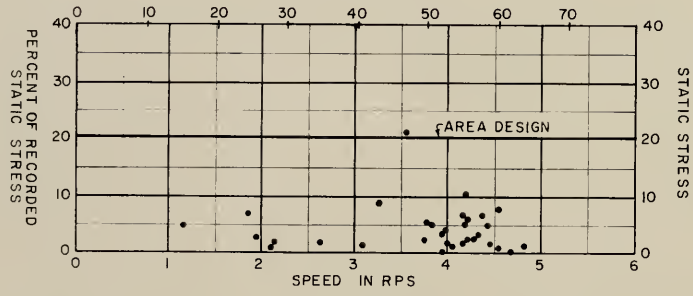
FIG 37
C.M. ST.P.& P.R.R. BRIDGE TESTS
46'-8¾ DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK+ HAMMER BLOW EFFECTS
MIKADO 2-8-2, CLASS "L-2b"



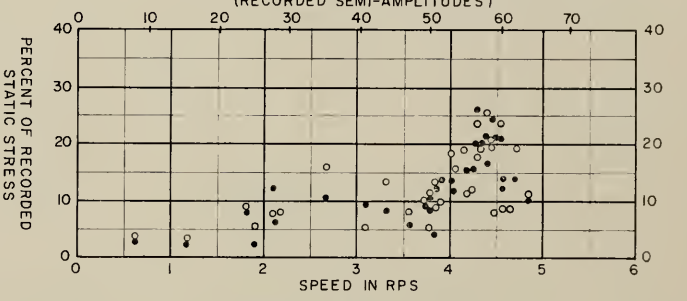
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL : o NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE : "n" = 6.24 VPS = 82.4 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

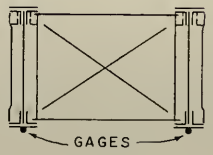
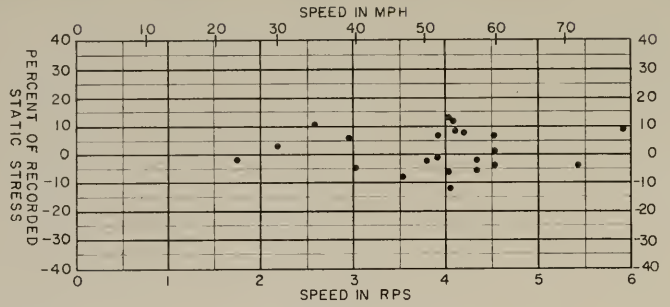
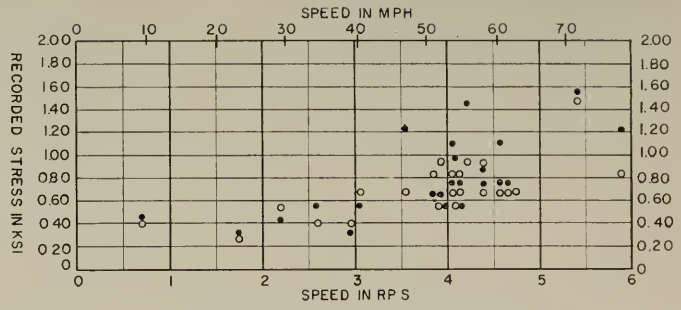


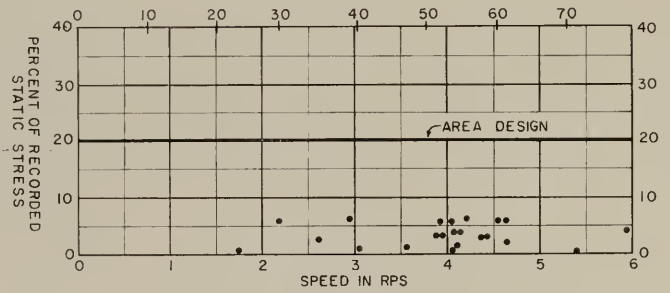
FIG 38
C.M.ST.P&P R.R. BRIDGE TESTS
46'-8¾" DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



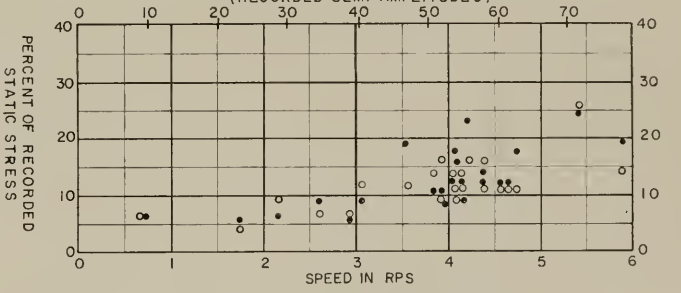
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)

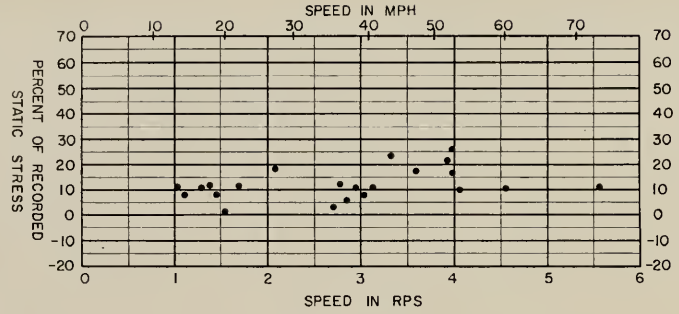


TRACK + HAMMER BLOW EFFECT

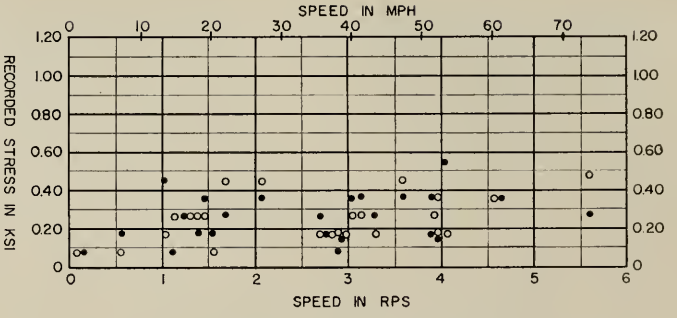
SYMBOL ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE "n" = 6.60 VPS = 8.72 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

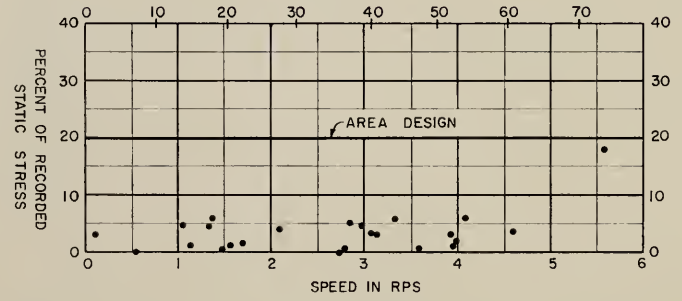
FIG. 39
C. M. ST. P. & P. RR. BRIDGE TESTS
46'-8¾" DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S3"



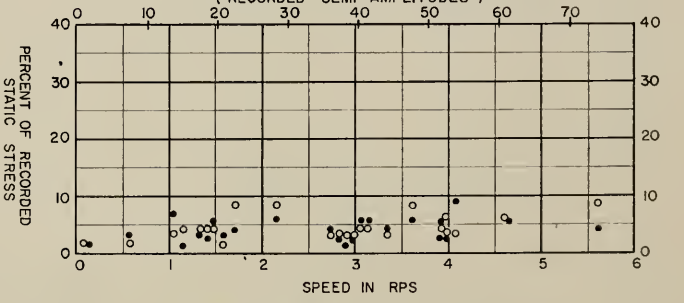
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 6.35 VPS = 84.0 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

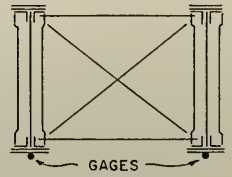
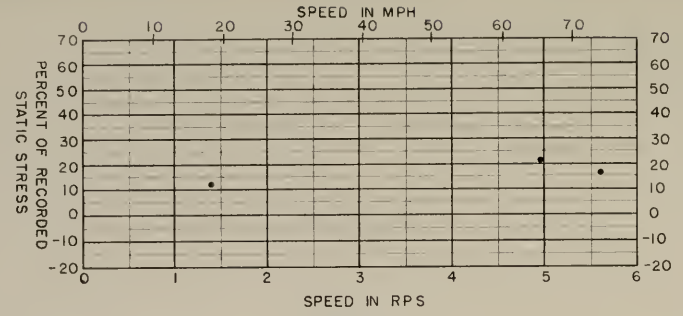
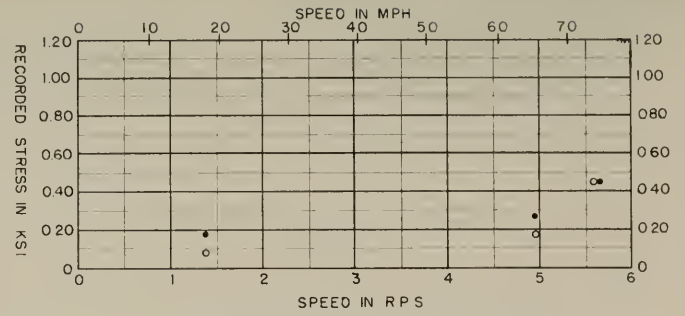


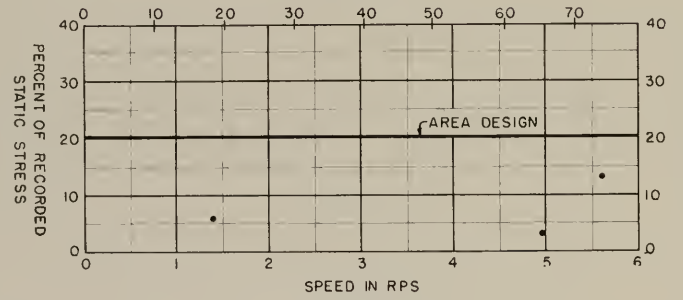
FIG. 40
C.M. ST. P & P. RR. BRIDGE TESTS
55'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S?"



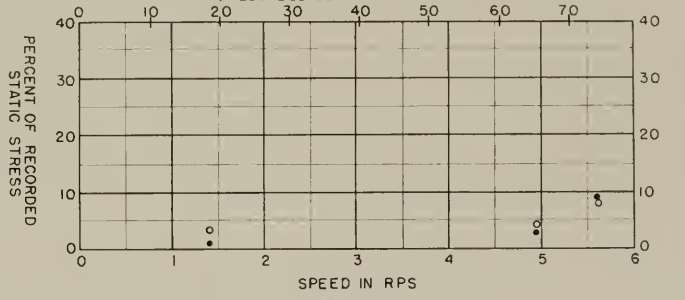
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI - AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE : "n" = 6.63 VPS 87.8 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

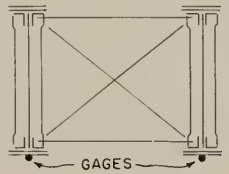
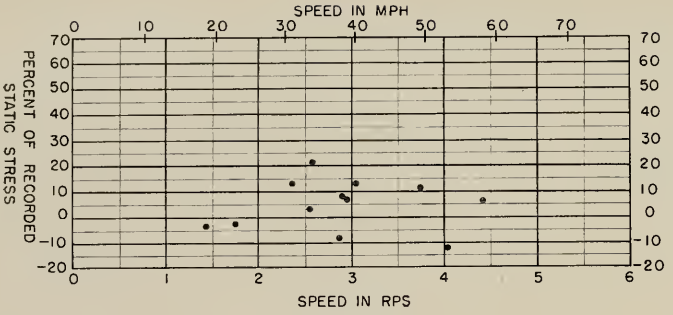
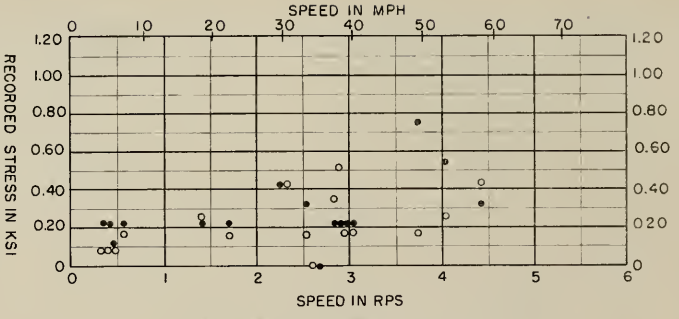


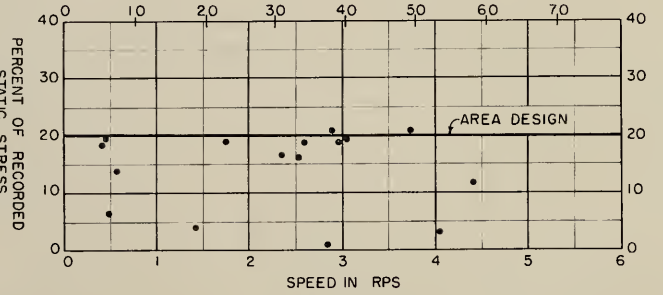
FIG. 41
C.M. ST. P & P. RR BRIDGE TESTS
55'-0 DECK PLATE GIRDER-EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4 – 8 – 4, CLASS "S3"



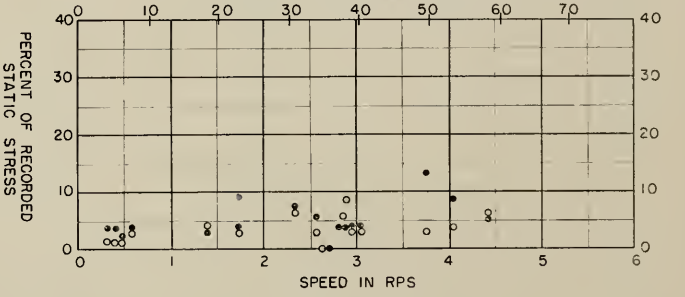
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 6.35 VPS = 84.0 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

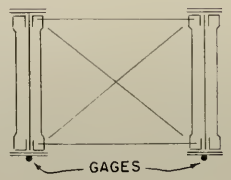
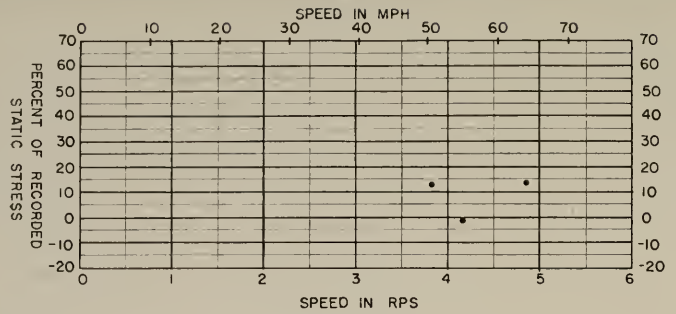
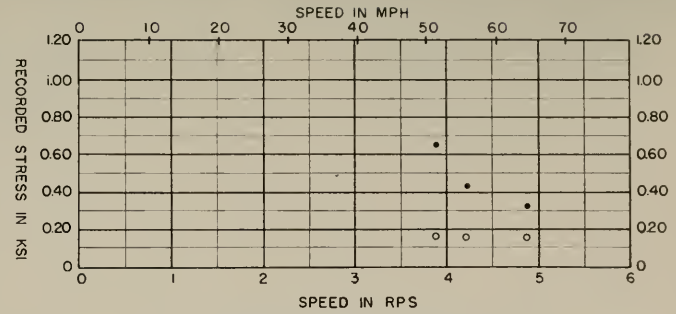


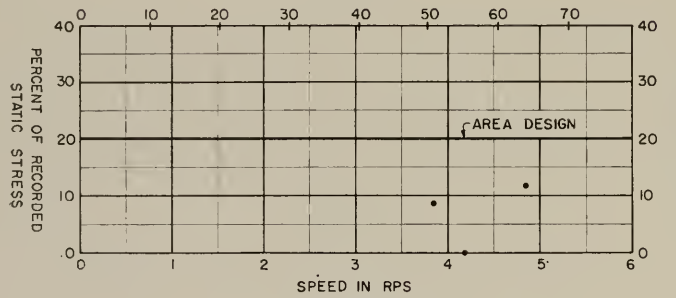
FIG. 42
C.M. ST. P. & P. R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER - WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



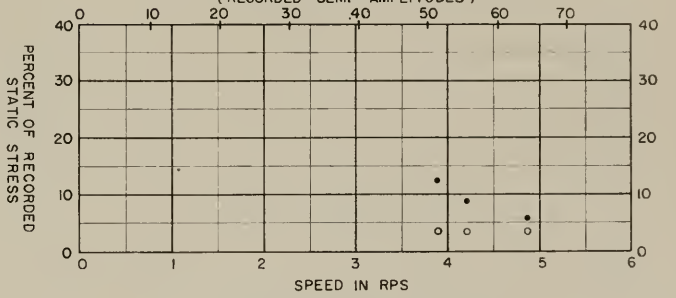
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI - AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 6.63 VPS = 87.8 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

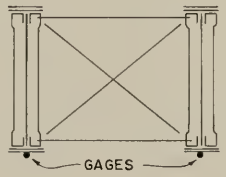


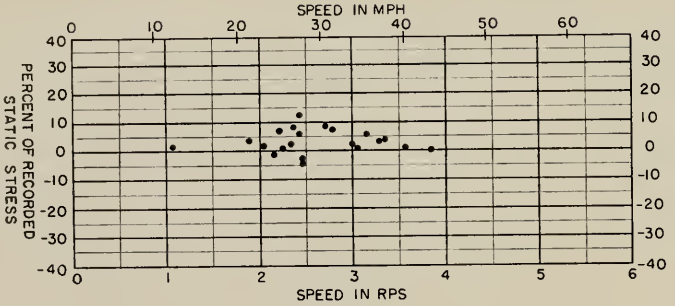
FIG. 43

C.M. ST. P & P R.R BRIDGE TESTS
55'-0 DECK PLATE GIRDER - WESTBOUND SPAN
OPEN TIMBER FLOOR

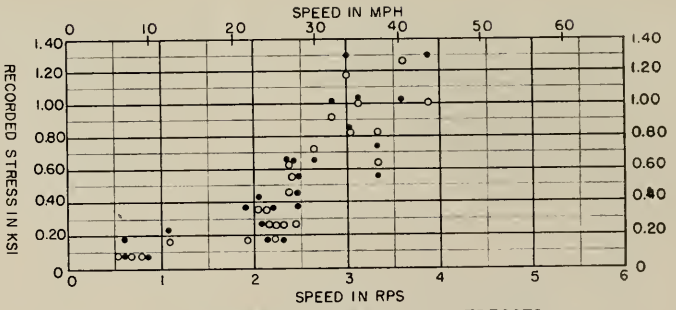
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS

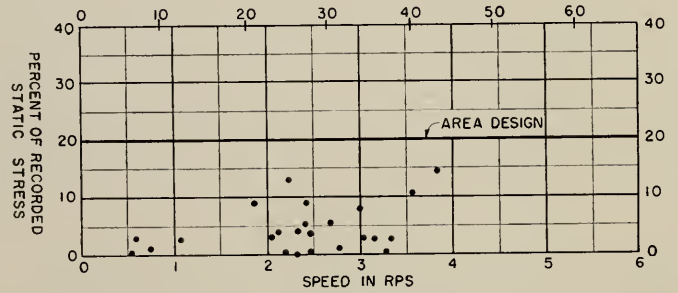
NORTHERN 4-8-4, CLASS "S3"



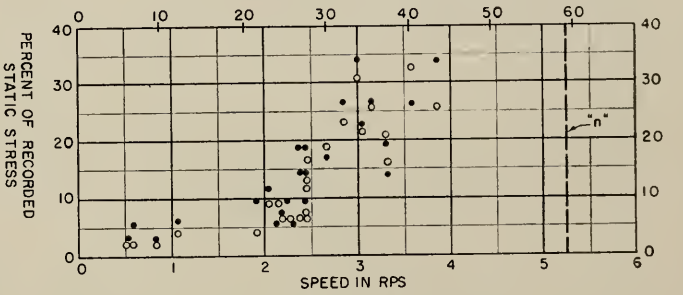
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK+ HAMMER BLOW EFFECT

SYMBOL · o NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE · "n" = 5.24 VPS = 59.0 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

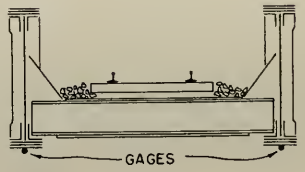
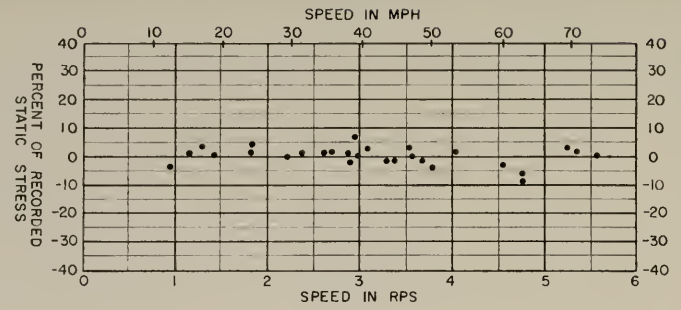
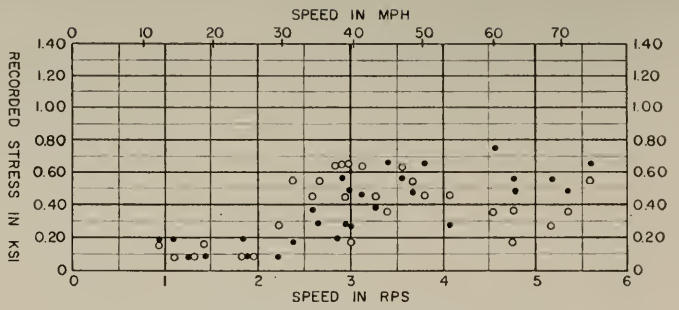


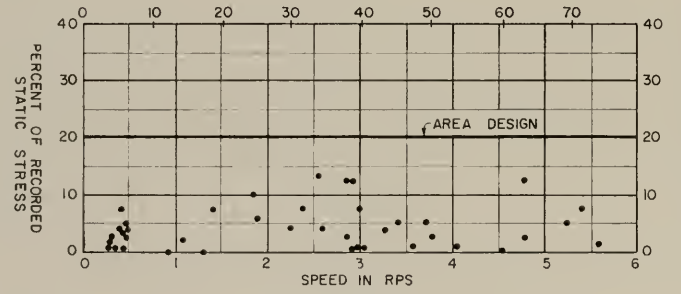
FIG. 44
C. M. ST. P. & P. R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
MIKADO 2-8-2, CLASS "L-2b"



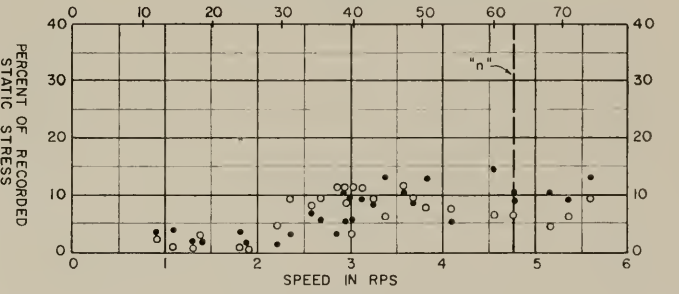
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: o NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE "n" = 4.76 VPS = 62.9 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

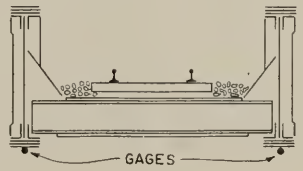
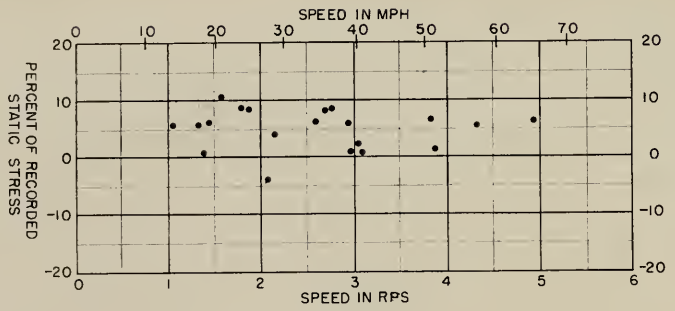
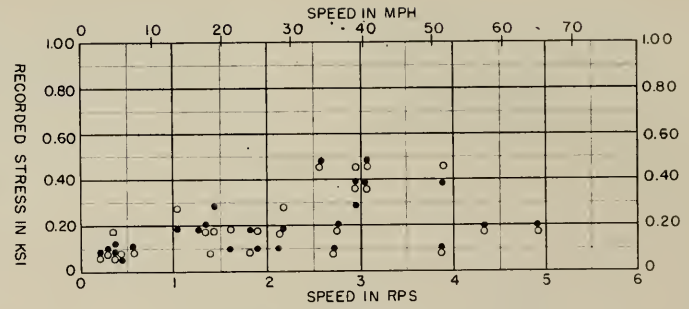


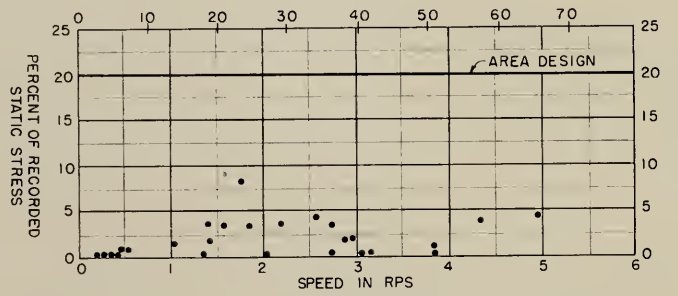
FIG.45
C.M.ST.P & P.R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S3"



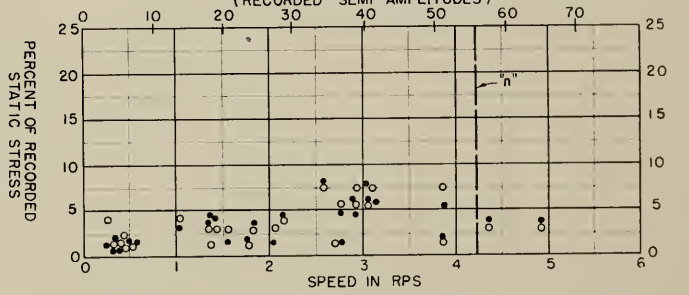
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 4.23 VPS = 55.8 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

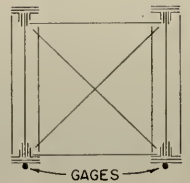
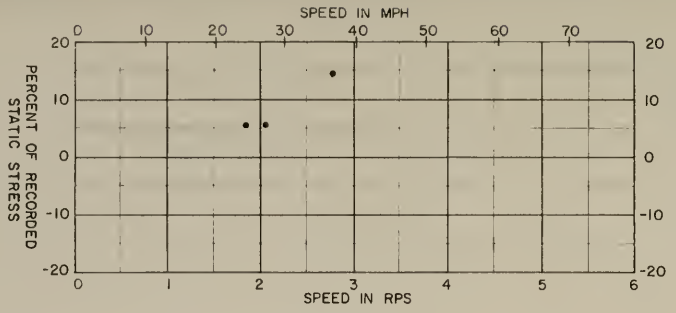
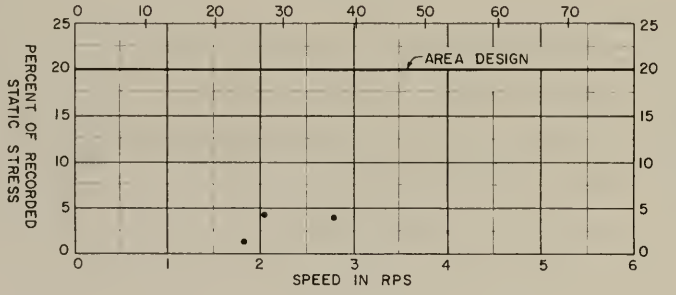


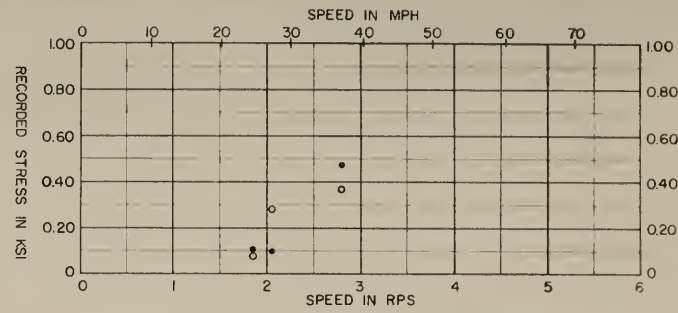
FIG. 46
C. M. ST. P. & P. R. R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



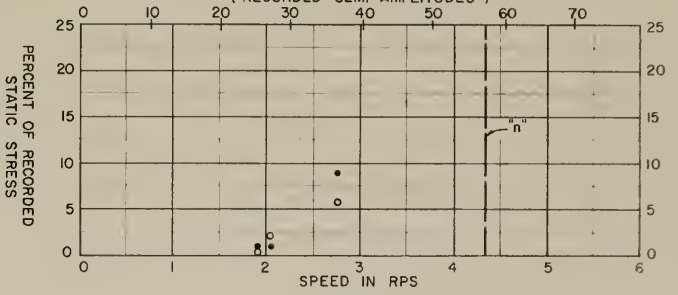
SPEED EFFECT



ROLL EFFECT
(AT RAIL CENTERS)



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 4.33 VPS = 57.2 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

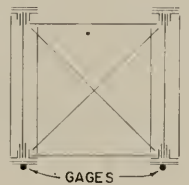
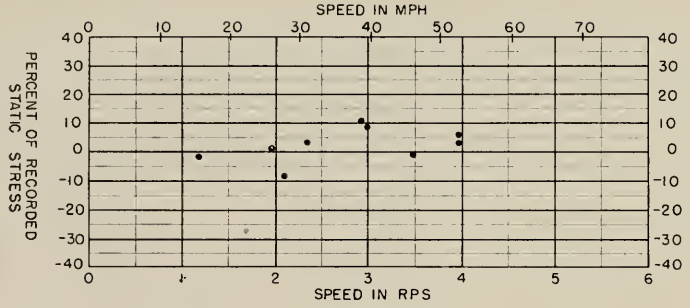
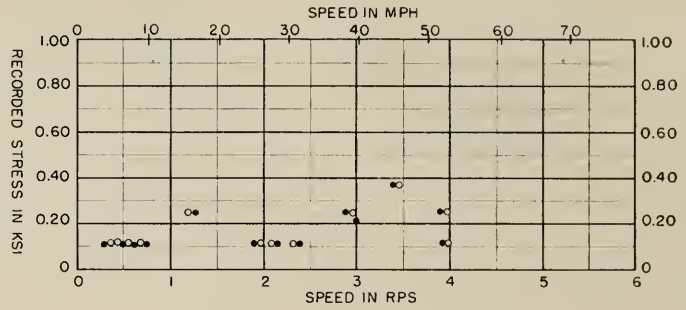


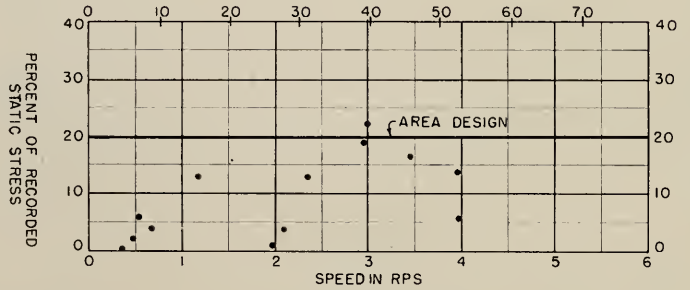
FIG. 47
C.M. ST. P. & P. R.R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S3"



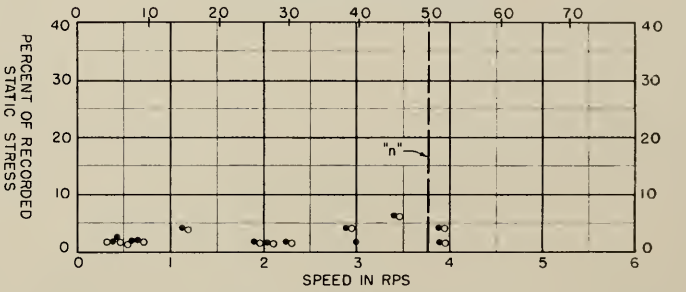
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 3.78 VPS = 49.8 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

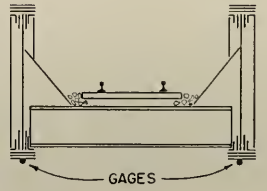
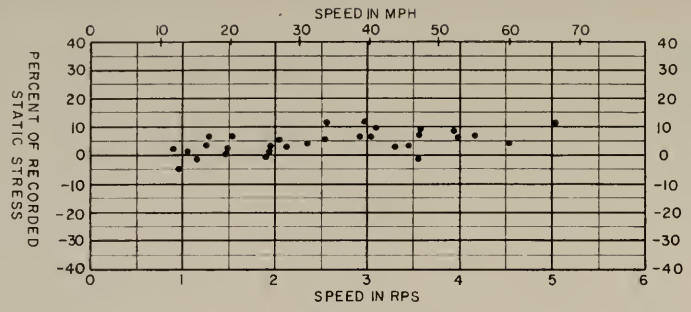
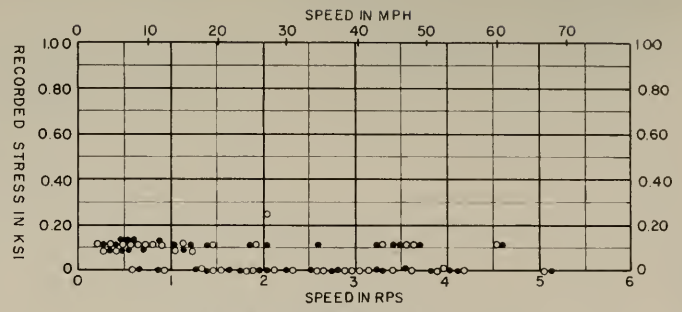


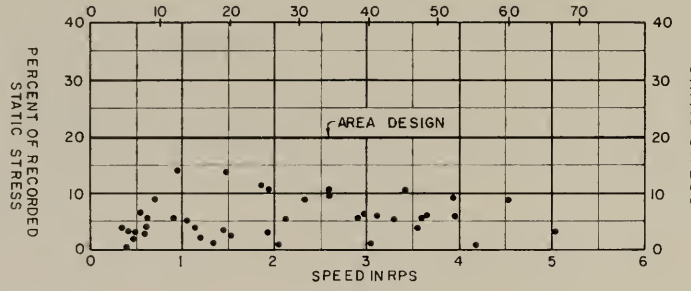
FIG. 48
C.M. ST. P.&P.R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
. NORTHERN 4-8-4, CLASS "S2"



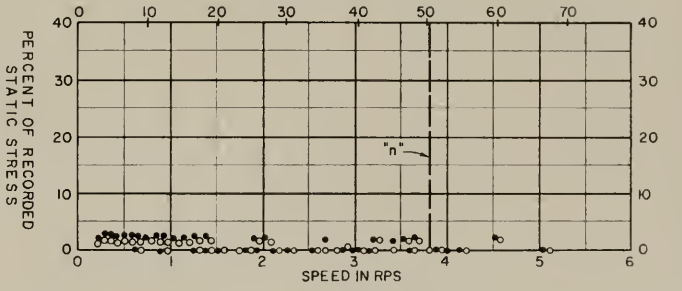
SPEED EFFECT



TOTAL TRACK+HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK+HAMMER BLOW EFFECT
● SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE "n" = 383 VPS = 50.6 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

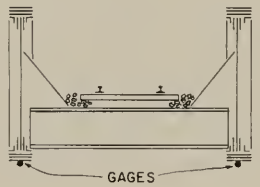
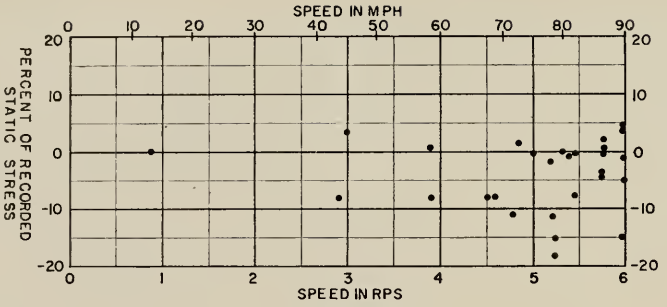


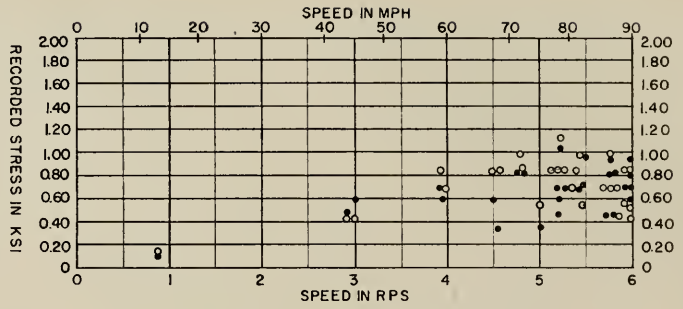
FIG. 49
C.M. ST.P.&P.RR BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS

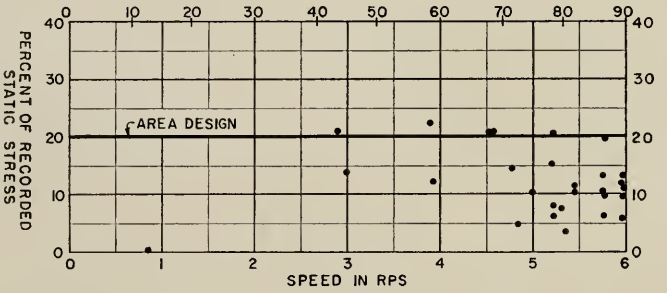
NORTHERN 4-8-4, CLASS "S3"



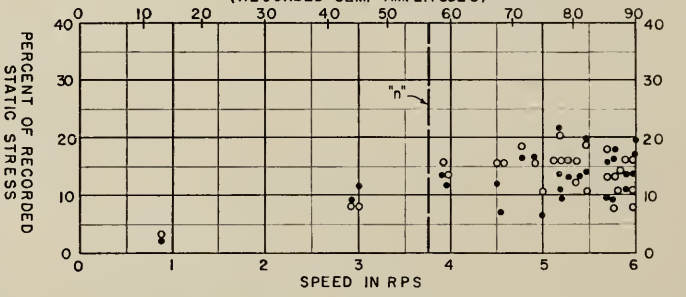
SPEED EFFECT



TOTAL TRACK+HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL : o NORTH GIRDER } TRACK+HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE · "n" = 3.74 VPS = 56.0 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

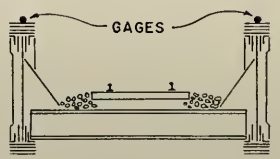
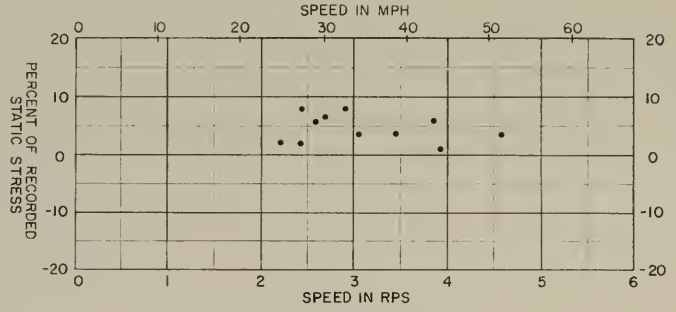
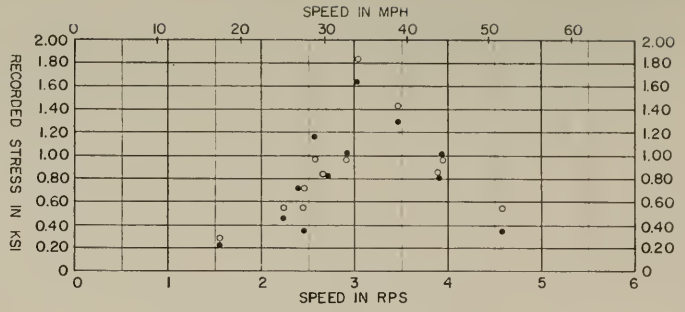


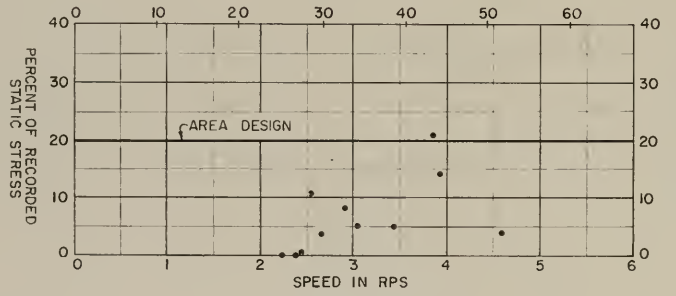
FIG. 50
C.M.ST.P & P.RR. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK+ HAMMER BLOW EFFECTS
ATLANTIC 4-4-2, CLASS "A"



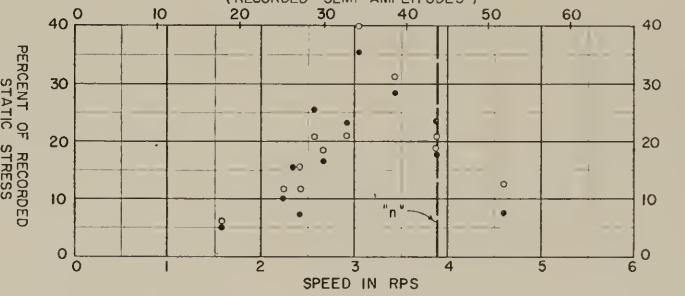
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 3.90 VPS = 44.0 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

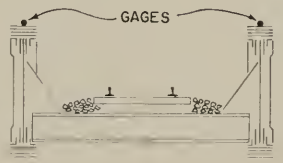
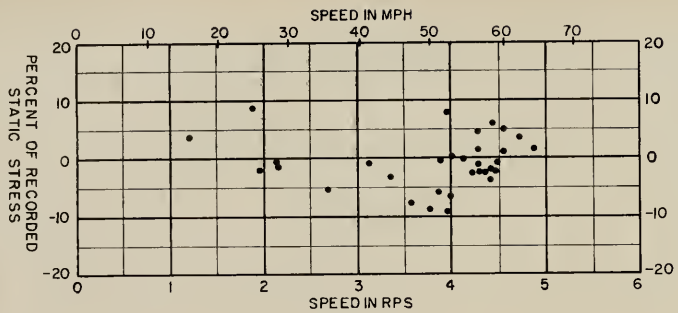
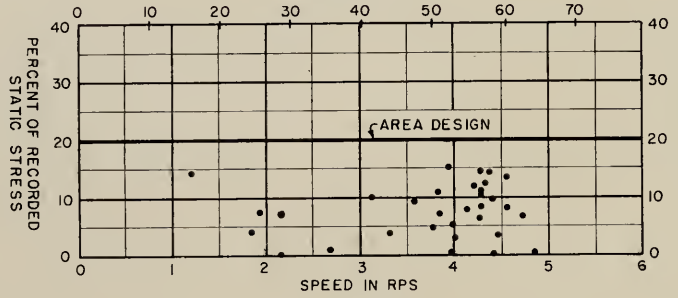


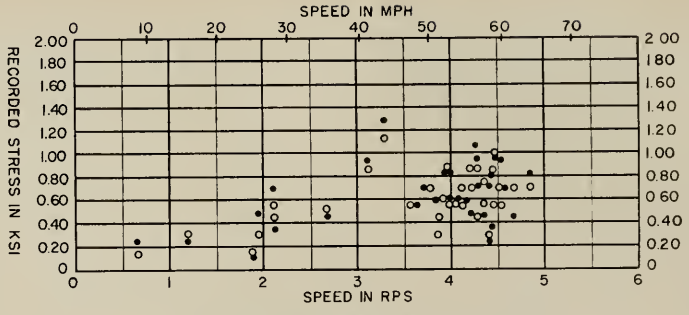
FIG. 51
C.M. ST P & P R.R BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
MIKADO 2-8-2, CLASS "L-2b"



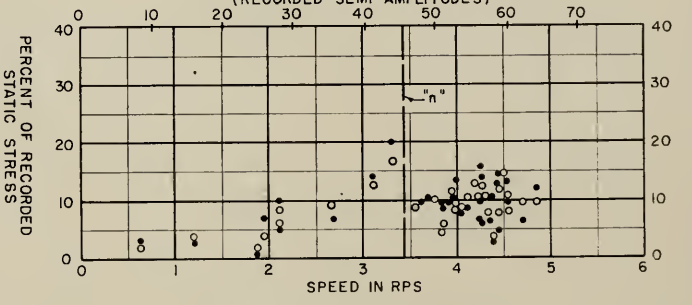
SPEED EFFECT



ROLL EFFECT
(AT RAIL CENTERS)



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



TRACK + HAMMER BLOW EFFECT

SYMBOL ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE : "n" = 3.44 VPS = 45.5 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

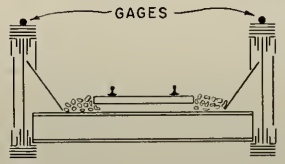
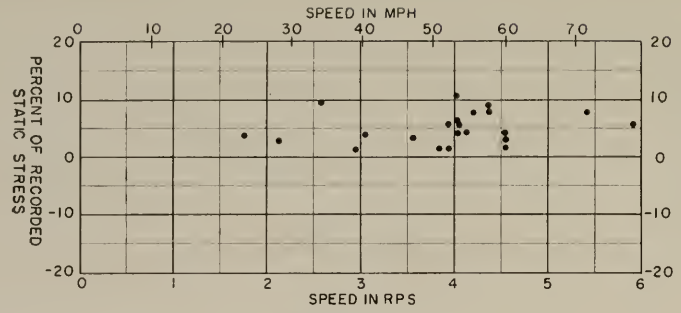
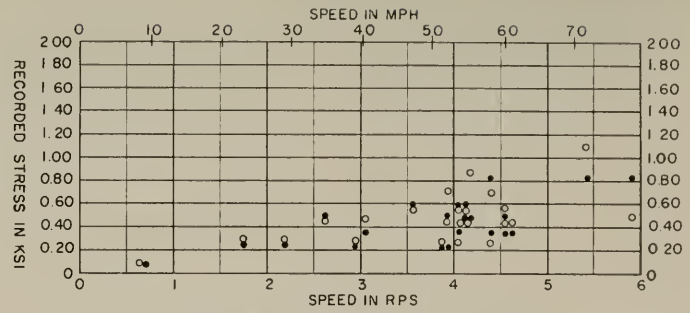


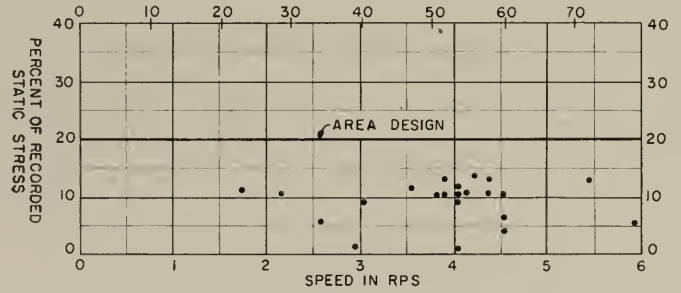
FIG. 52
C.M. ST.P & P.RR. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



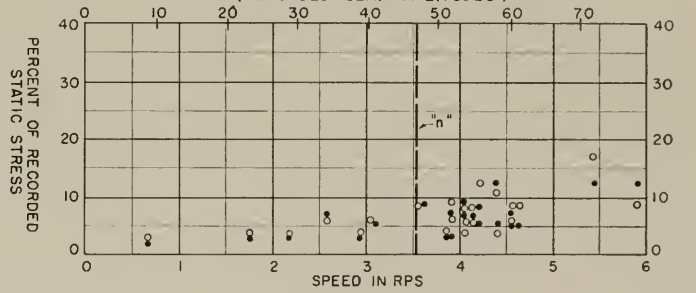
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL . o NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
• SOUTH GIRDER }
• SPEED EFFECT, ROLL EFFECT

NOTE : "n" = 3.53 VPS = 46.6 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

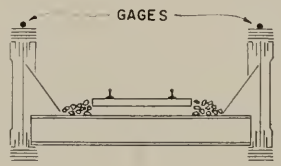
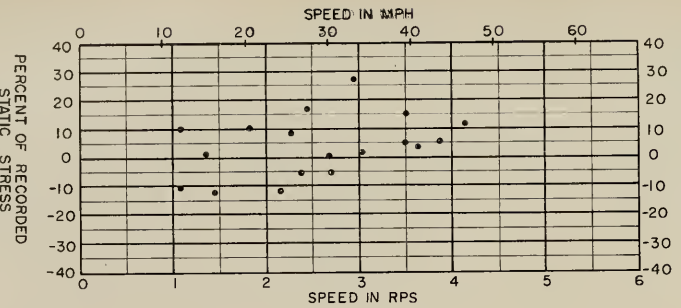
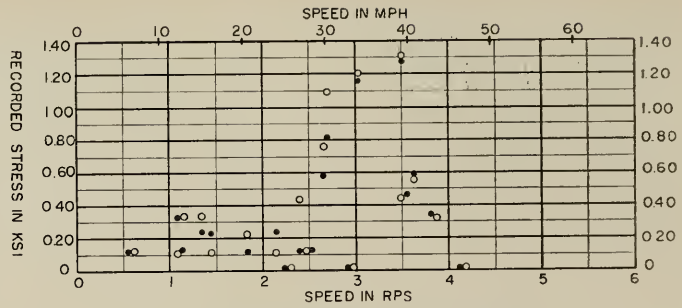


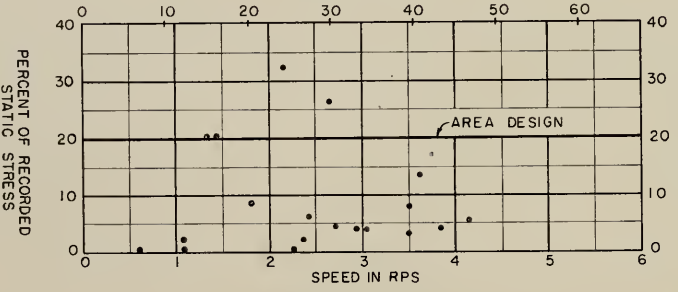
FIG 53
C.M. ST. P & P. R.R. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "33"



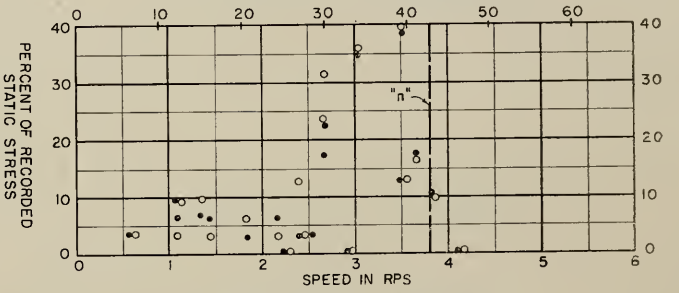
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI - AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL : ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 3.80 VPS = 42 9 MPH
SEE FIG 15 FOR LOCOMOTIVE DIAGRAM

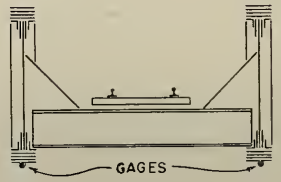
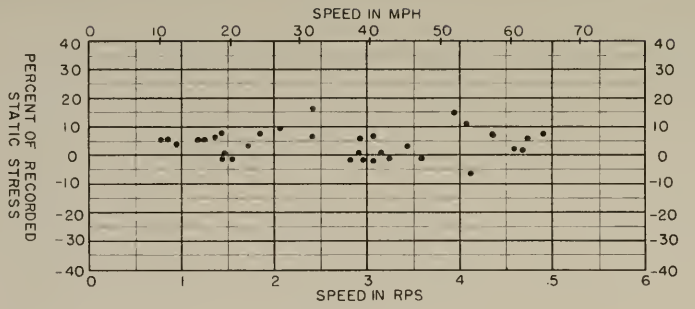
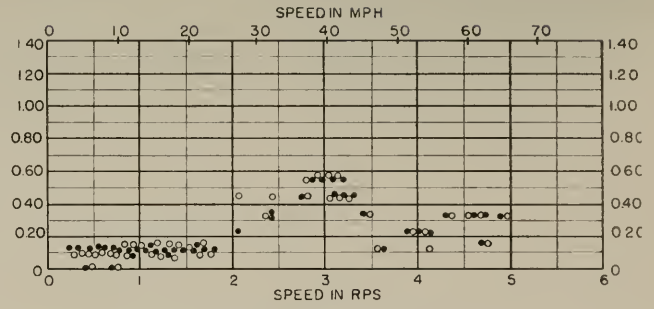


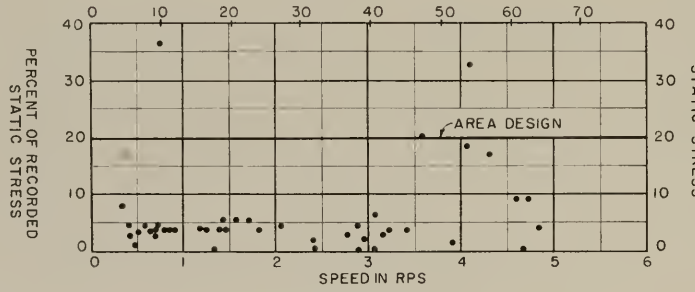
FIG. 54
C. M. ST. P. & P. R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
MIKADO 2-8-2, CLASS "L-2b"



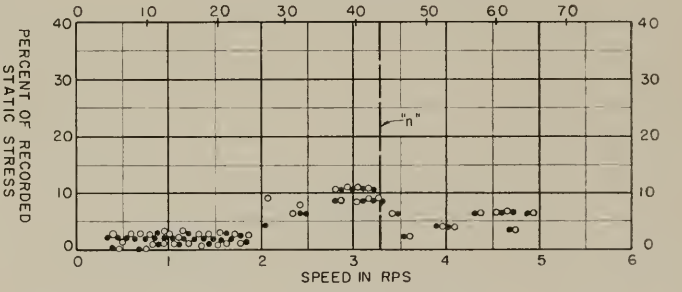
SPEED EFFECT



TOTAL TRACK+HAMMER BLOW STRESSES
(RECORDED SEMI-AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK+HAMMER BLOW EFFECT

SYMBOL. ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE "n" = 3.29 VPS = 43.5 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

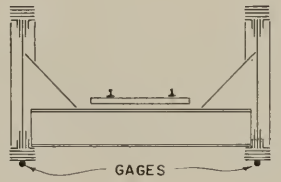
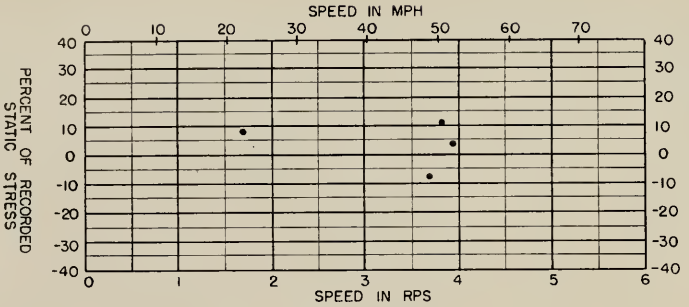
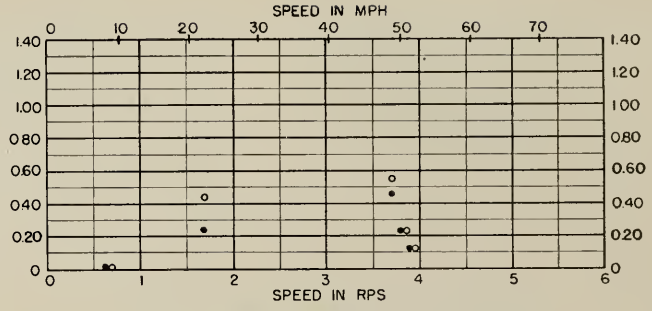


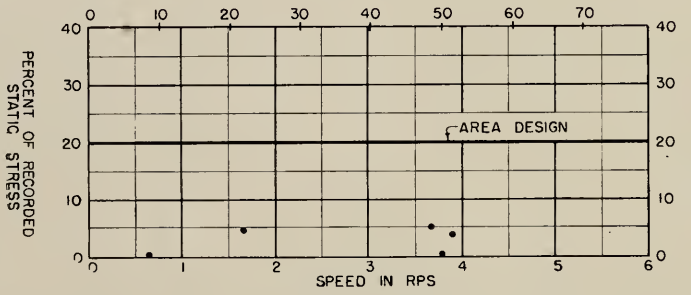
FIG. 55
C.M. ST. P & P RR. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK+ HAMMER BLOW EFFECTS
NORTHERN 4-8-4, CLASS "S2"



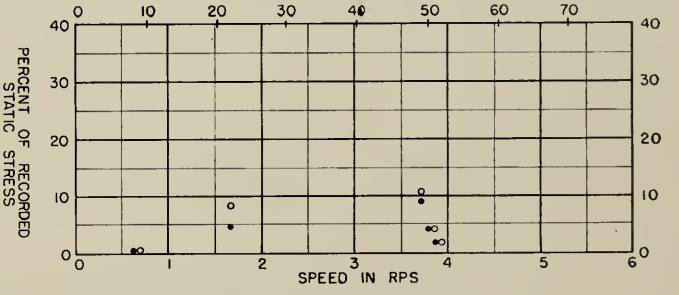
SPEED EFFECT



TOTAL TRACK + HAMMER BLOW STRESSES
(RECORDED SEMI- AMPLITUDES)



ROLL EFFECT
(AT RAIL CENTERS)



TRACK + HAMMER BLOW EFFECT

SYMBOL: ○ NORTH GIRDER } TRACK + HAMMER BLOW EFFECT
● SOUTH GIRDER }
● SPEED EFFECT, ROLL EFFECT

NOTE: "n" = 333 VPS = 44.0 MPH
SEE FIG. 15 FOR LOCOMOTIVE DIAGRAM

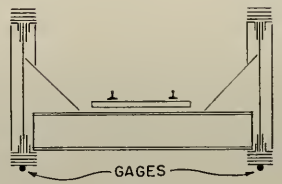
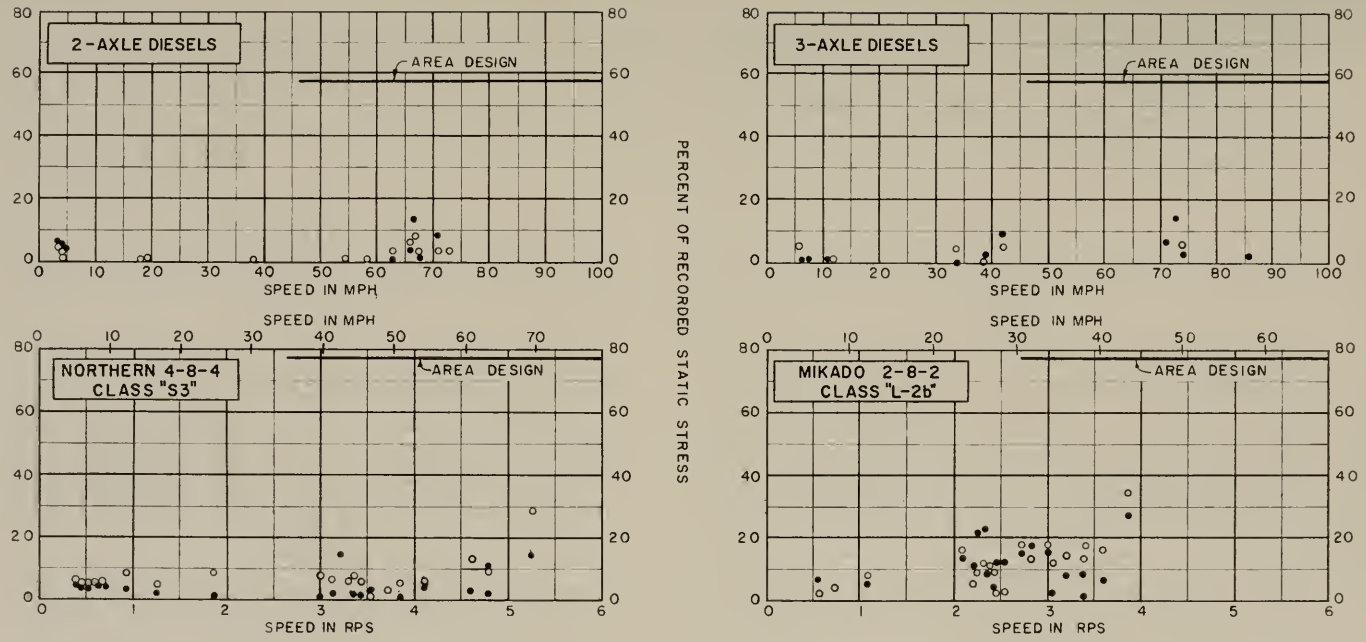


FIG. 56
C.M. ST. P. & P. R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
SPEED, ROLL AND TRACK + HAMMER BLOW EFFECTS
NORTHERN 4-8-4. CLASS "S3"



SYMBOL: ○ NORTH BEAMS
● SOUTH BEAMS

NOTE . CLASS 2-AXLE DIESELS "n" = 8.67 VPS
" 3-AXLE DIESELS "n" = 8.40 VPS
" "L-2b" "n" = 7.65 VPS = 86.2 MPH
" "S-3" "n" = 7.00 VPS = 92.5 MPH

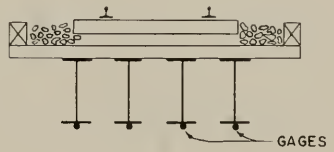
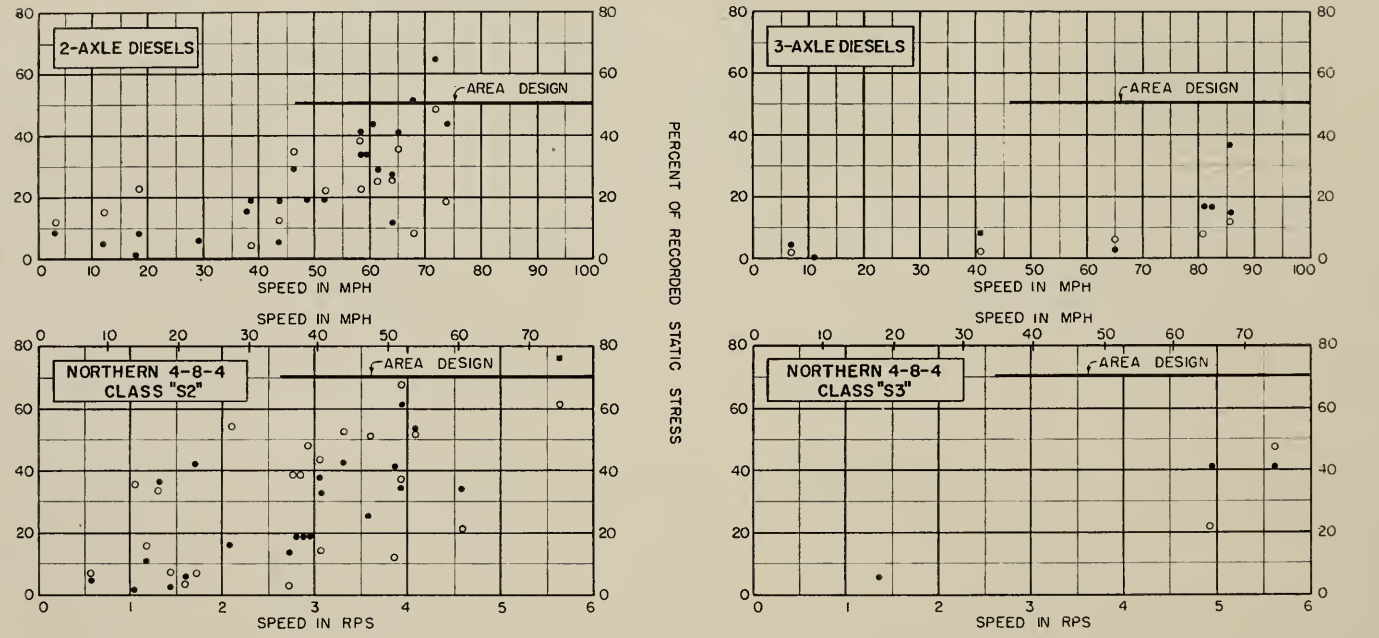


FIG. 57
C.M.ST.P.&P. R.R. BRIDGE TESTS
35'-0 WF BEAM SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF BEAMS
TOTAL IMPACTS
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "L-2b" & "S3"



SYMBOL. ○ NORTH GIRDER
● SOUTH GIRDER

NOTE
CLASS	2-AXLE	DIESEL	"n" =	11.18	VPS
"	3-AXLE	DIESEL	"n" =	10.10	VPS
"	"S2"	"n" =	8.77 VPS =	115.8	MPH
"	"S3"	"n" =	9.15 VPS =	120.8	MPH

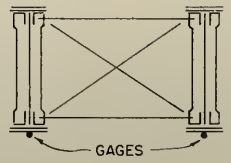
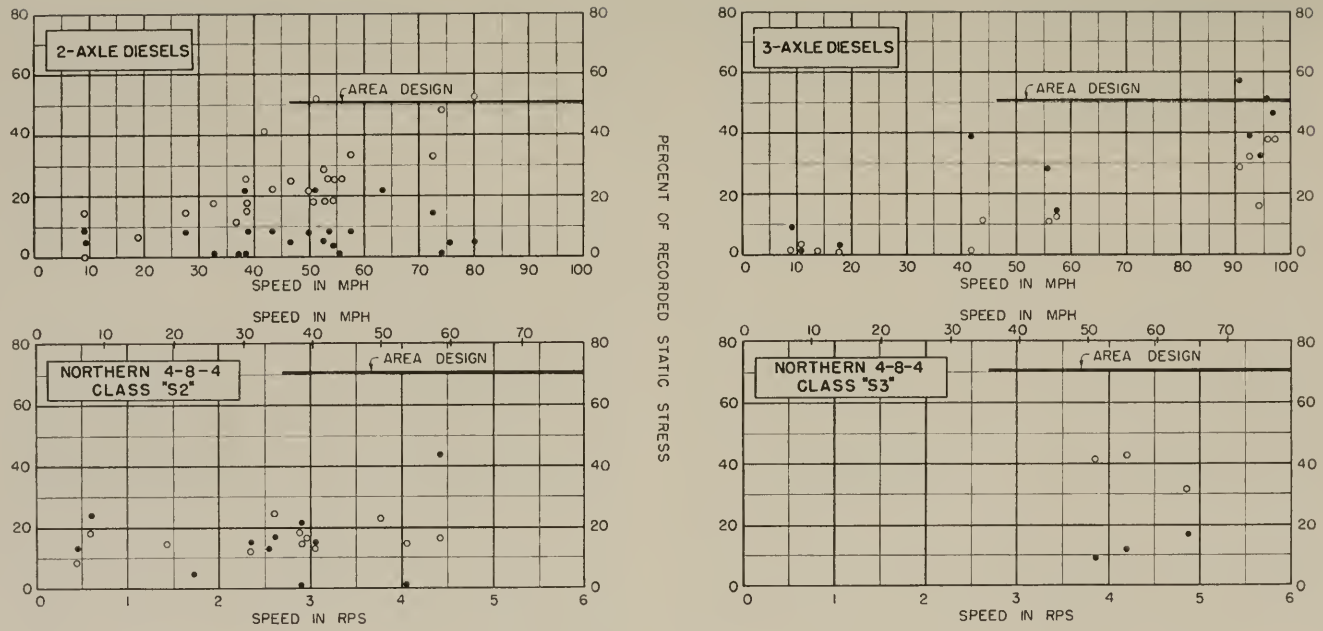


FIG. 58
C.M. ST. P. & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASSES 2-AXLE
& 3-AXLE DIESELS, S2 & S3



SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

NOTE:
CLASS	2-AXLE	DIESEL	"n" =	11.18	VPS
"	3-AXLE	DIESEL	"n" =	10.88	VPS
"	"S2"	"n" =	8.78	VPS =	116.0 MPH
"	"S3"	"n" =	9.15	VPS =	120.8 MPH

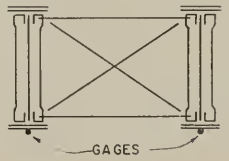
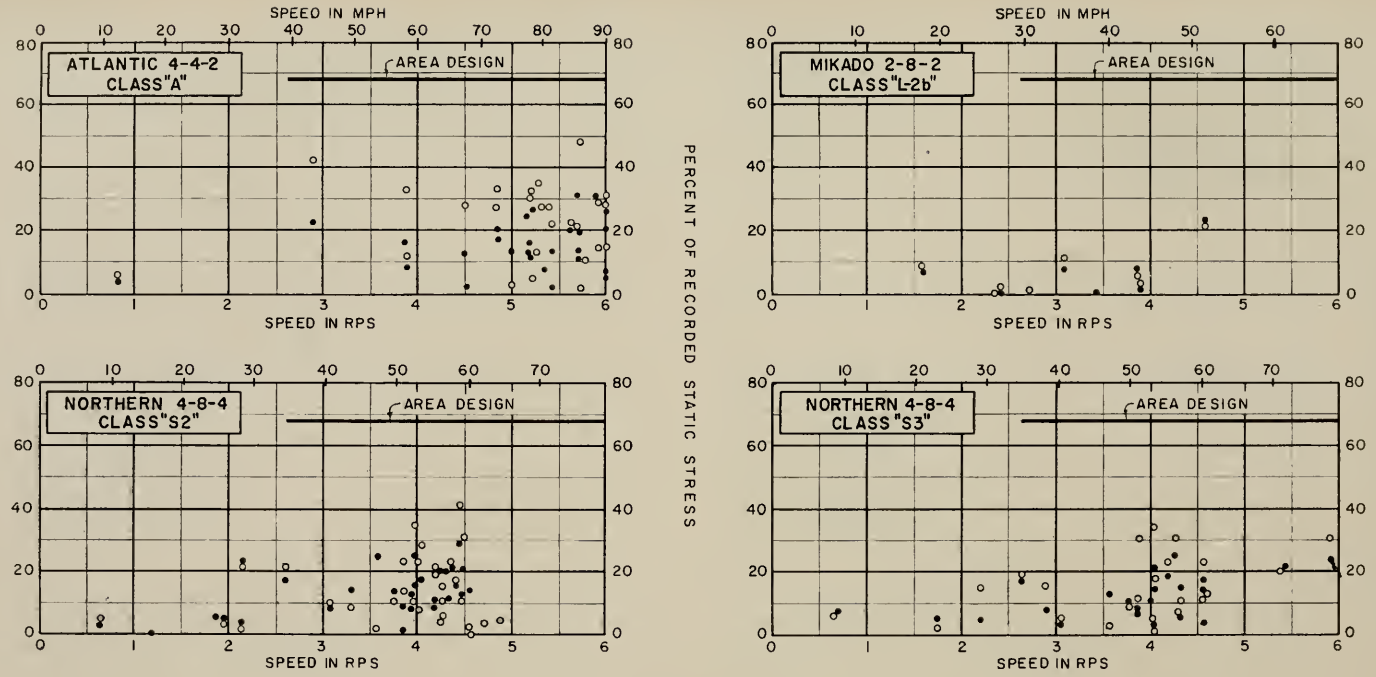


FIG. 59

C. M. ST. P & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER - WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

TOTAL IMPACTS

LOCOMOTIVE CLASSES 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"



SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

NOTE CLASS "A" "n" = 7.19 VPS = 107.5 MPH
" "L2-b" "n" = 6.52 VPS = 73.5 MPH
" "S2" "n" = 6.24 VPS = 82.4 MPH
" "S3" "n" = 6.60 VPS = 87.2 MPH

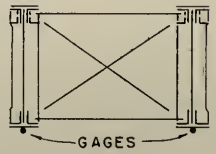
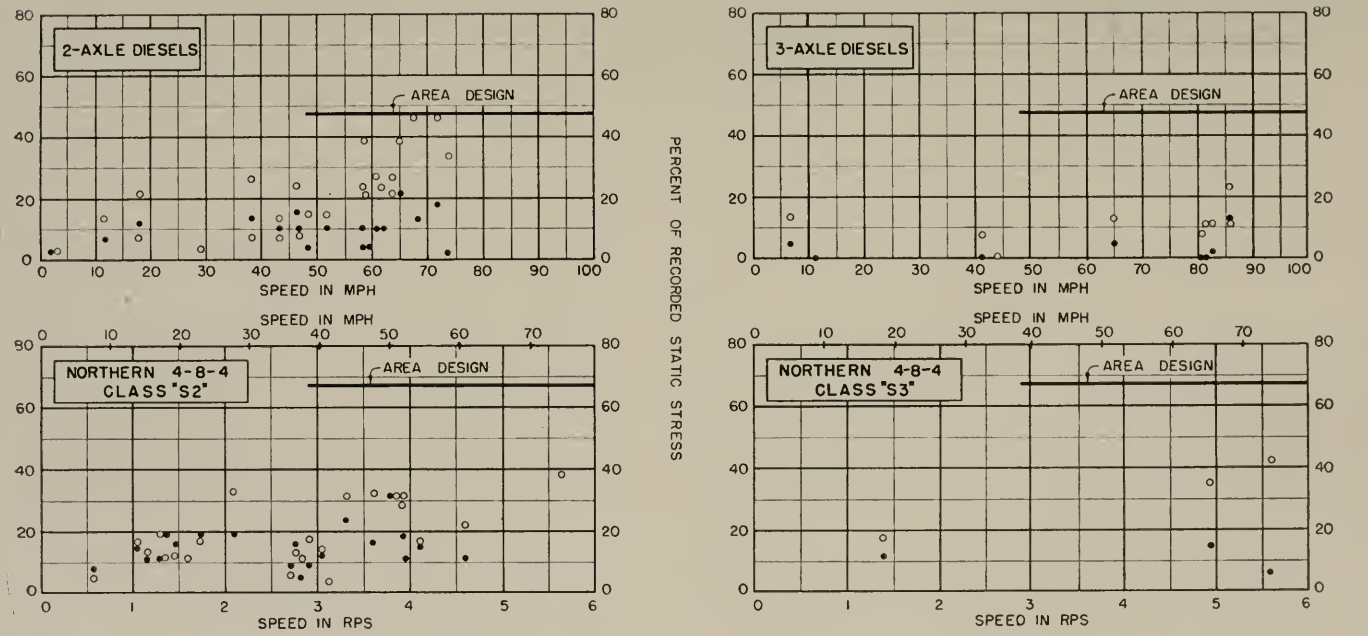


FIG. 60
C.M.ST.P.&P.R.R. BRIDGE TESTS
46 1 8 3/4 DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASS: "A", "L-2b", "S2" & "S3"



SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

NOTE: CLASS 2-AXLE DIESEL "n" = 8.52 VPS
" 3-AXLE DIESEL "n" = 7.90 VPS
"S2" "n" = 6.35 = 84.0 MPH
"S3" "n" = 6.63 = 87.8 MPH

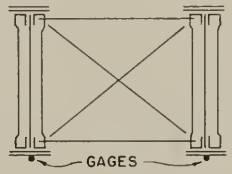
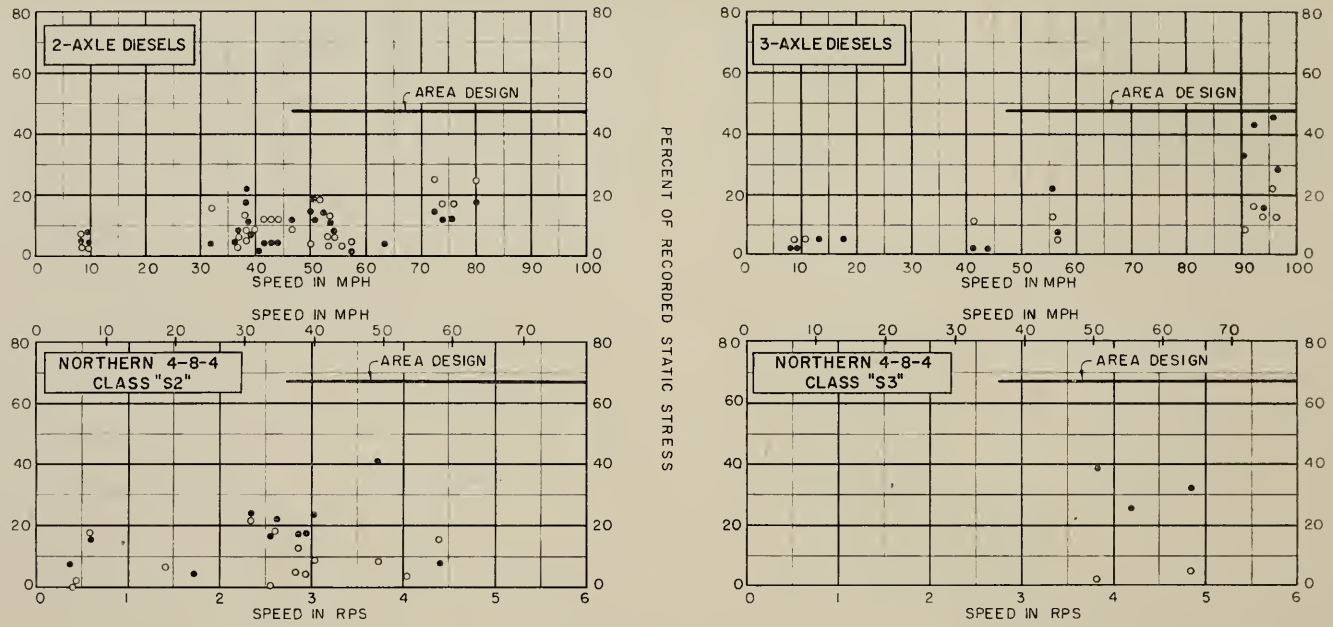


FIG. 61
C.M. ST. P. & P. R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "S2 & "S3"



SYMBOL : ○ NORTH GIRDER
• SOUTH GIRDER

NOTE CLASS "2- AXLE DIESELS" "n"=8.30 VPS
" "3- AXLE DIESELS" "n"=8.02 VPS
" "S2" "n"= 6.35 VPS = 84.0 MPH
" "S3 "n"= 6.63 VPS = 87.8 MPH

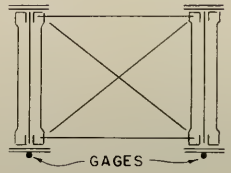
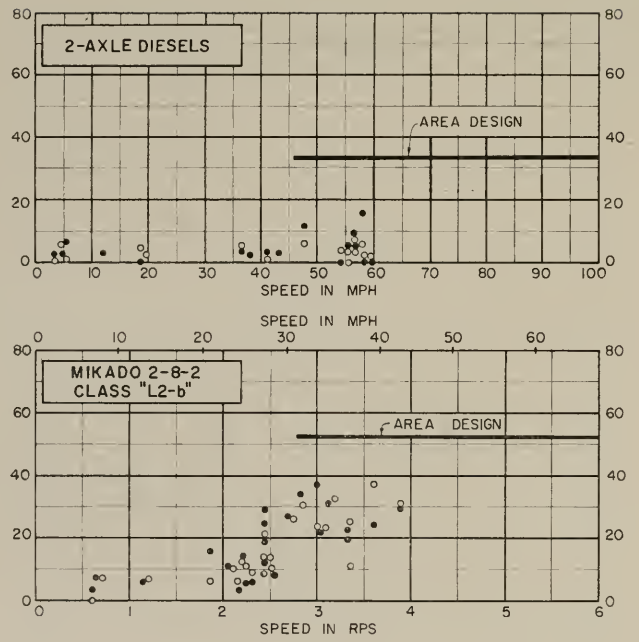
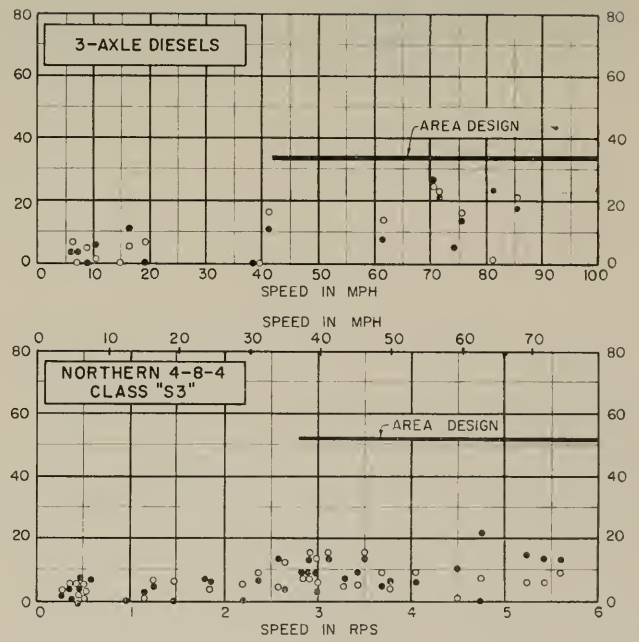


FIG. 62
C.M. ST P& P R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, S2 & S3





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

NOTE CLASS 2-AXLE DIESELS "n" = 5.61 VPS
" 3-AXLE DIESELS "n" = 5.78 VPS
" "L-2b" "n" = 5.24 VPS = 59.0 MPH
" "S3" "n" = 4.76 VPS = 62.9 MPH

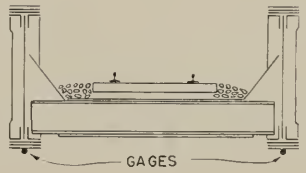
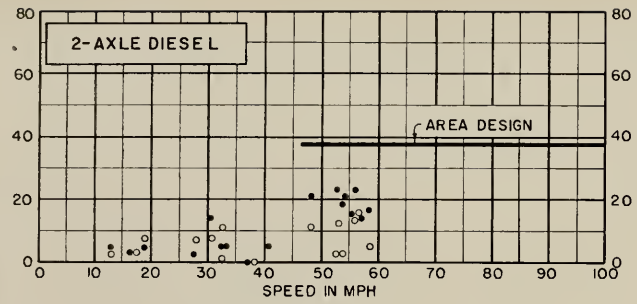
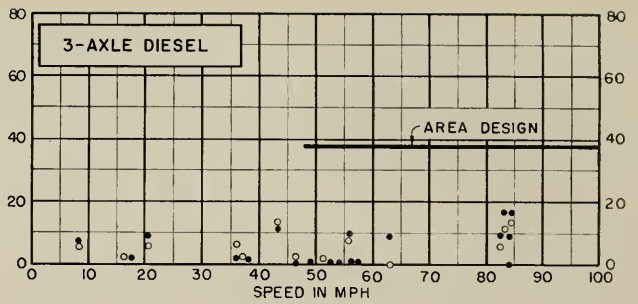
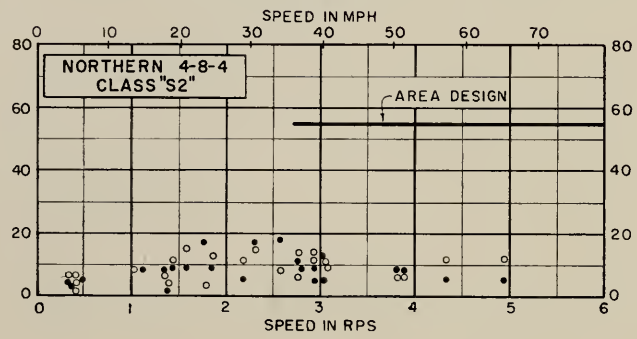
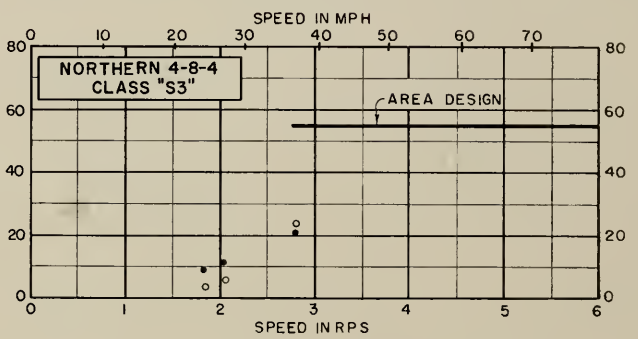


FIG. 63
C. M. ST. P & P. R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "L2b" & "S3"









PERCENT OF RECORDED STATIC STRESS

SYMBOL. o NORTH GIRDER
• SOUTH GIRDER

NOTE : CLASS 2-AXLE DIESELS "n"=5.24 VPS
" 3-AXLE DIESELS "n"=4.75 VPS
" "S2" "n"=4.23 VPS = 55.8 MPH
" "S3" "n"=4.33 VPS = 57.2 MPH

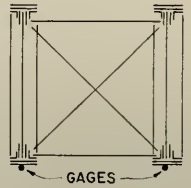
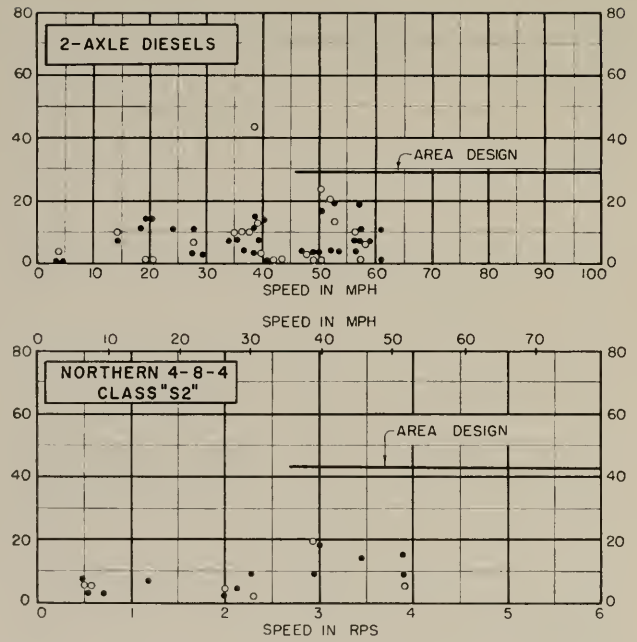
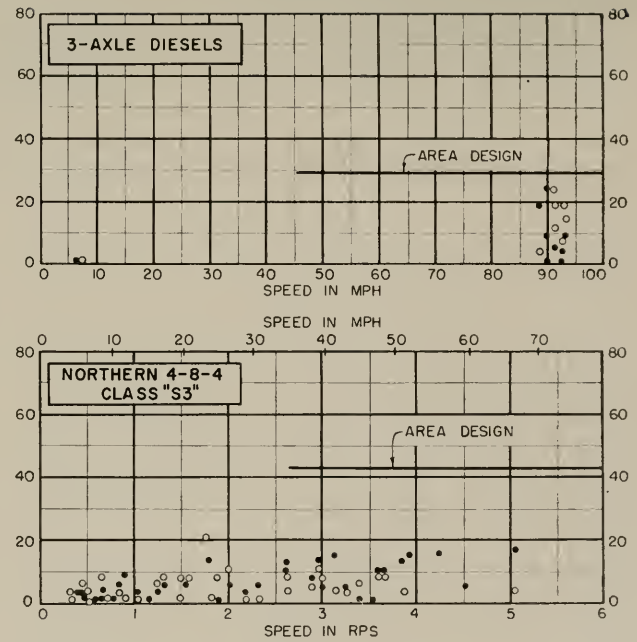


FIG. 64
C.M.ST.P.& P. R.R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

NOTE CLASS 2-AXLE DIESELS "n" = 4.37 VPS
" 3-AXLE DIESELS "n" = 4.58 VPS
" "S2" "n" = 3.78 VPS = 49.8 MPH
" "S3" "n" = 3.83 VPS = 50.6 MPH

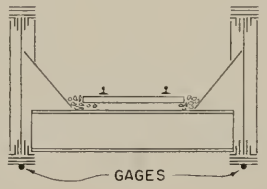
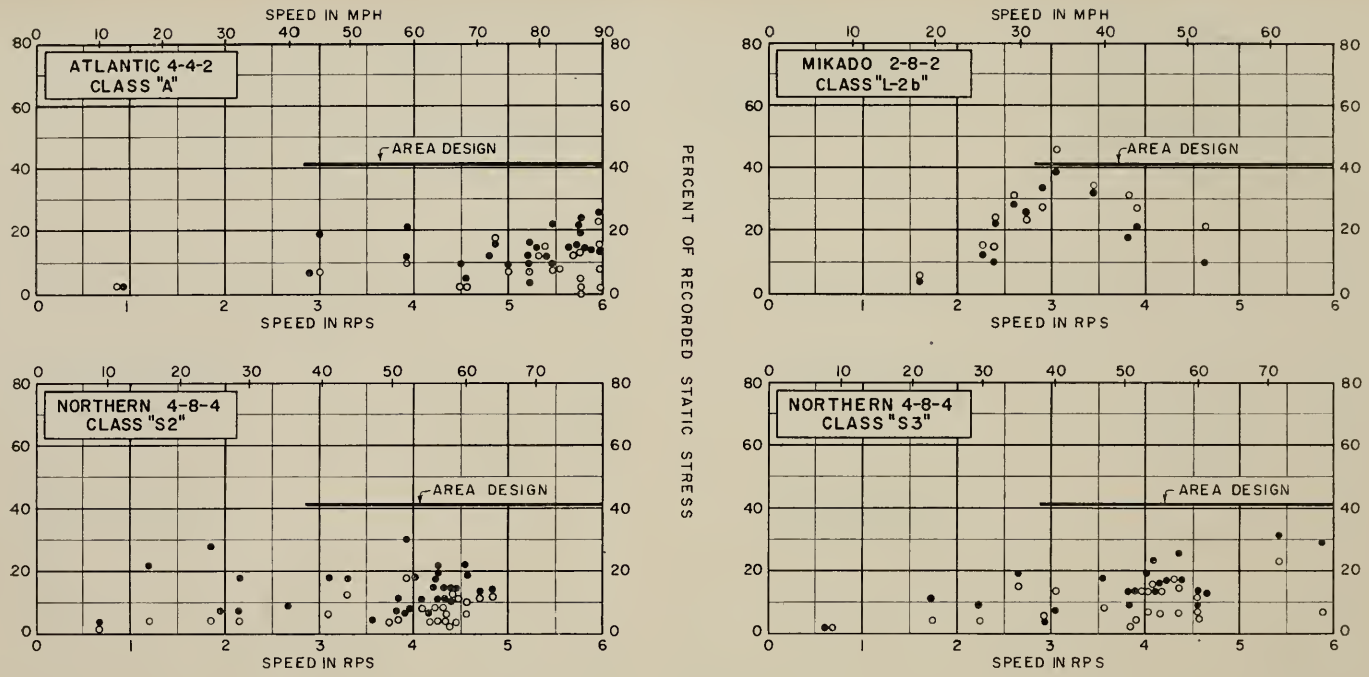


FIG 65
C.M. ST. P.&P. R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"



SYMBOL: o NORTH GIRDER
• SOUTH GIRDER

NOTE : CLASS "A" "n" = 3.74 VPS = 56.0 MPH
" "L2-b" "n" = 3.90 VPS = 44.0 MPH
" "S2" "n" = 3.44 VPS = 45.5 MPH
" "S3" "n" = 3.53 VPS = 46.6 MPH

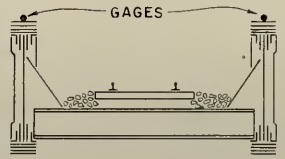
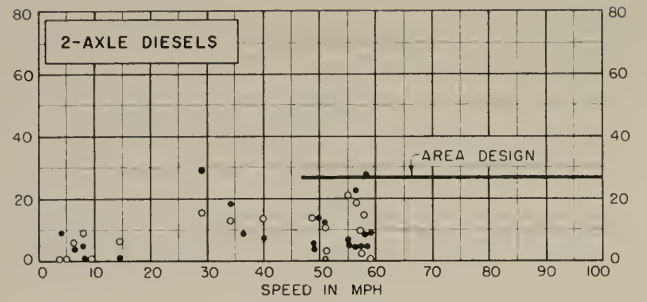
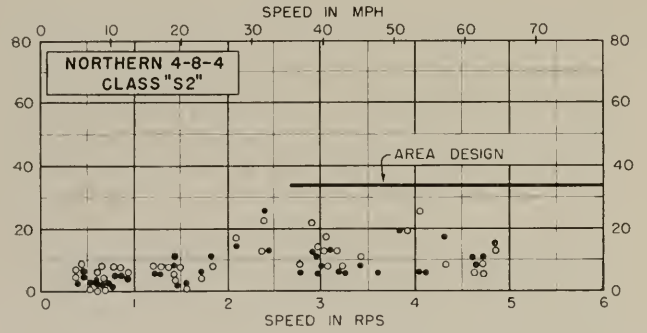
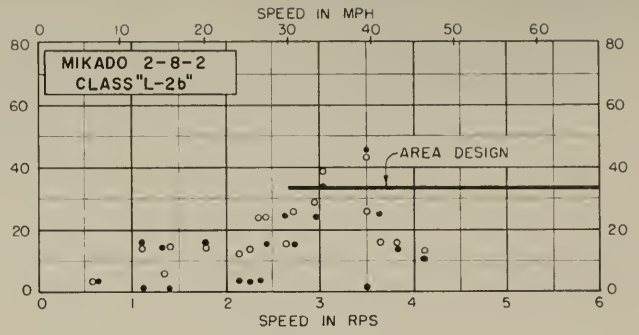


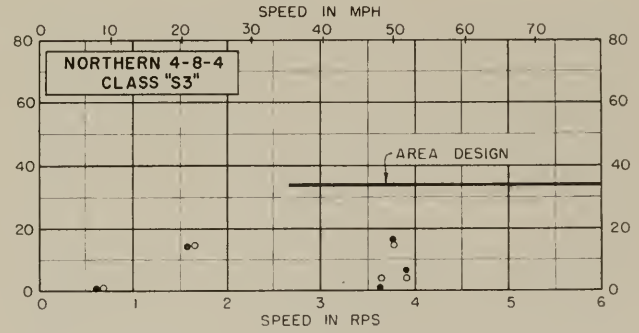
FIG. 66
C.M.ST.P. & P. R.R. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASS: "A", "L2-b", "S2" & "S3"





PERCENT OF RECORDED STATIC STRESS





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

NOTE CLASS 2-AXLE DIESEL "n" = 3.77 VPS
" "L2b" "n" = 3.80 VPS = 42.9 MPH
" "S2" "n" = 3.29 VPS = 43.5 MPH
" "S3" "n" = 3.33 VPS = 44.0 MPH

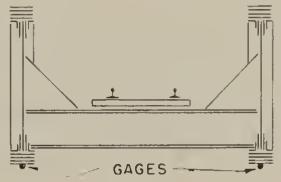
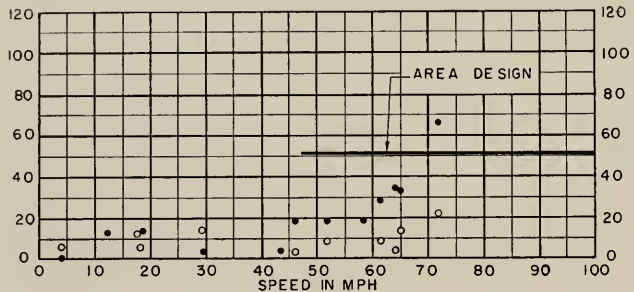
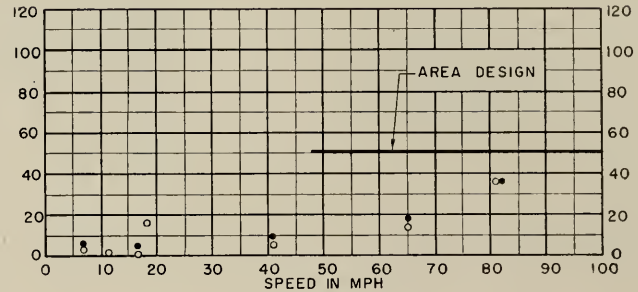
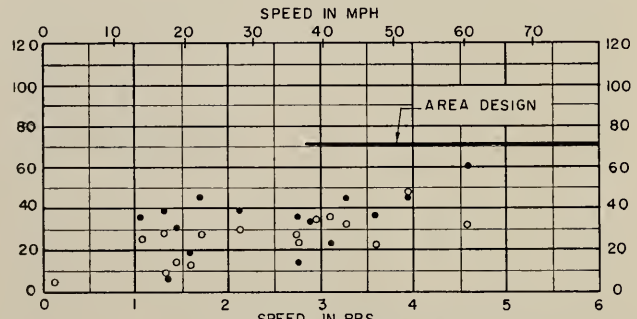


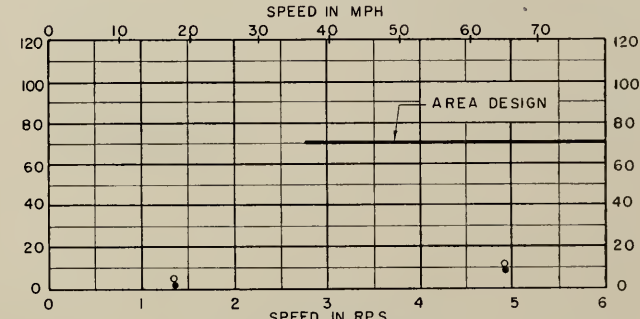
FIG. 67
C.M. ST. P & P. R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
TOTAL IMPACTS
LOCOMOTIVE CLASS 2-AXLE DIESEL.
"L-2b", "S2" & "S3"





PERCENT OF RECORDED STATIC STRESS





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

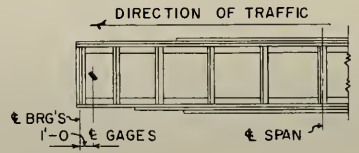
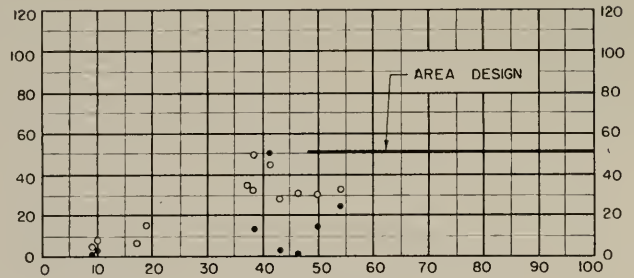
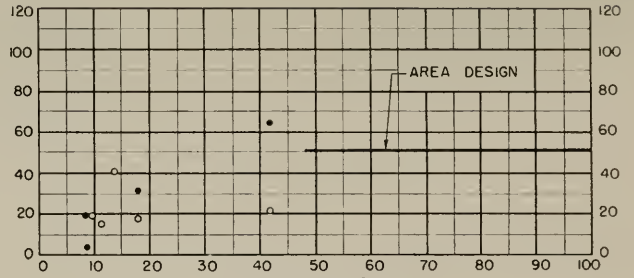
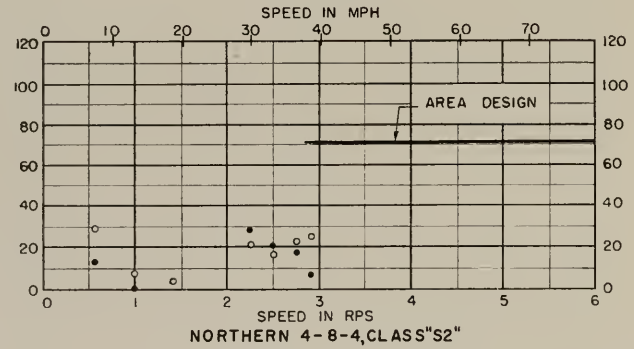


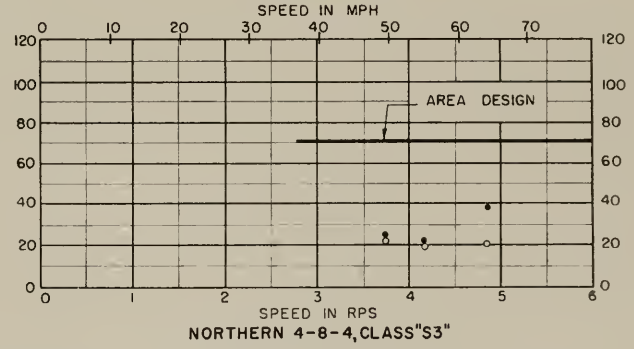
FIG 68
C.M. ST.P. & P. R.R. BRIDGE TESTS
40'-0 EASTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL: o NORTH GIRDER
• SOUTH GIRDER

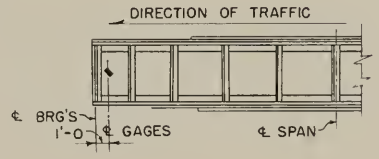
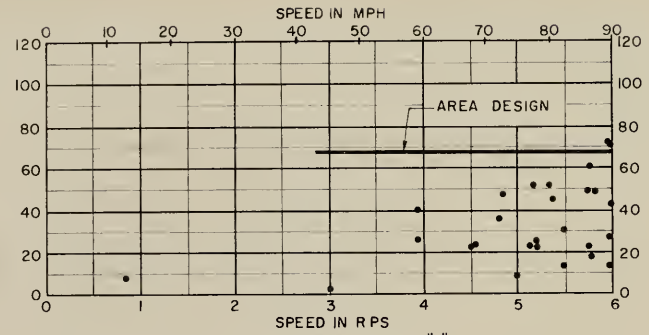
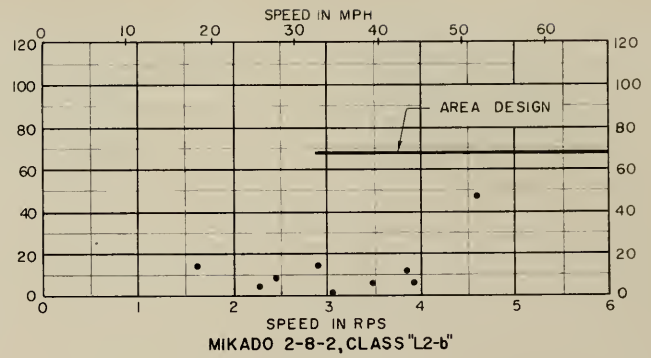
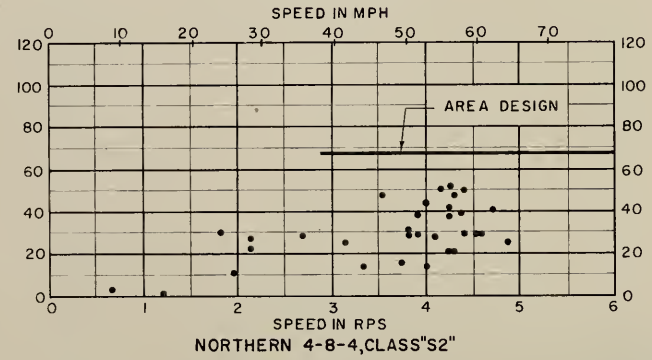
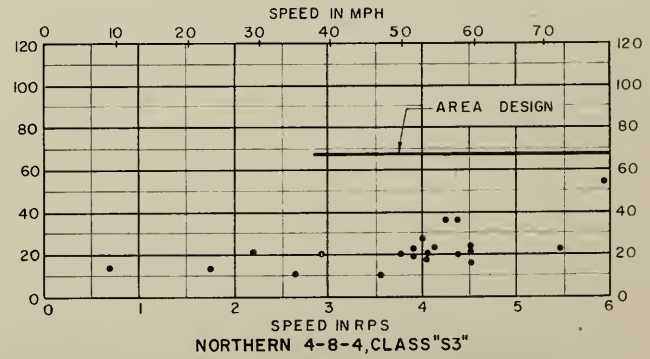


FIG. 69
C. M. ST. P. & P. R.R. BRIDGE TESTS
40'-0 WESTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





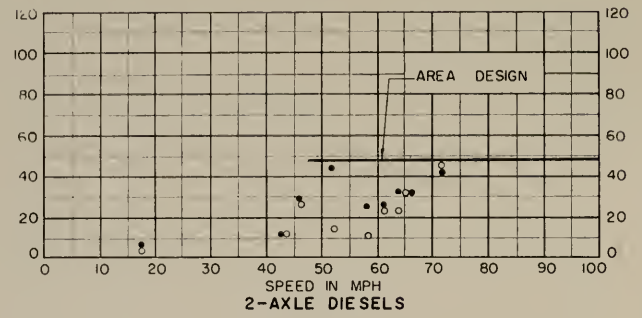


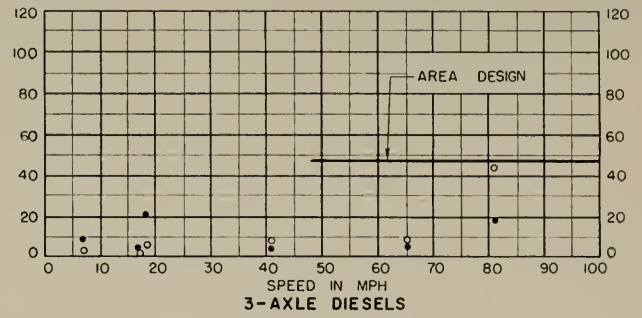


PERCENT OF RECORDED STATIC STRESS

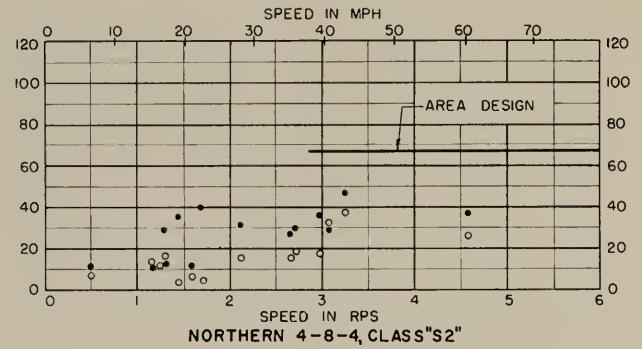
SYMBOL: • SOUTH GIRDER

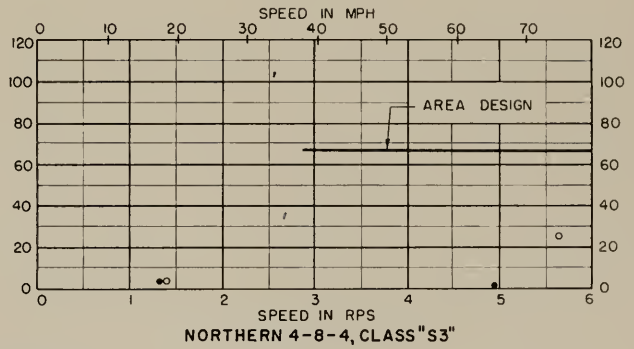
FIG. 70
C.M.ST.P.&P.R.R. BRIDGE TESTS
46'-8¾ DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

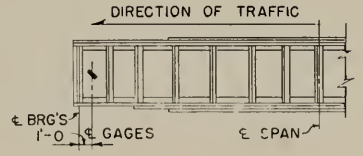
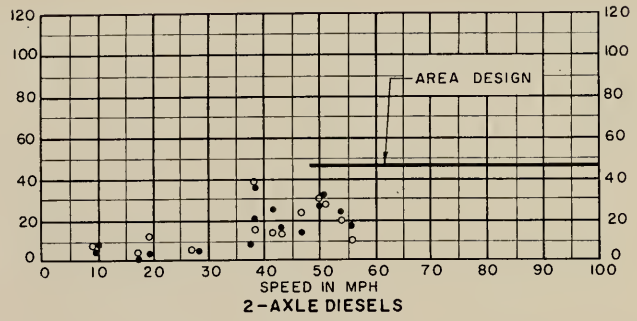
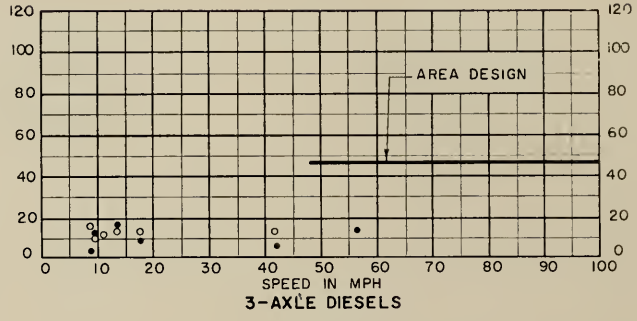
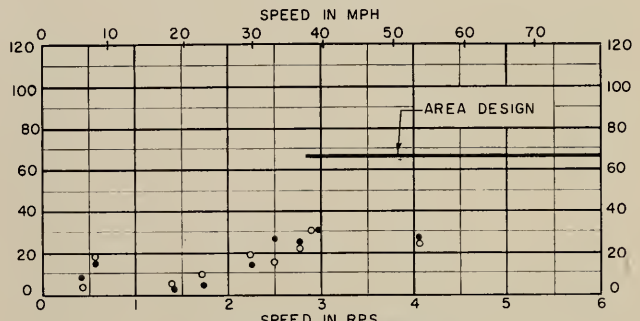


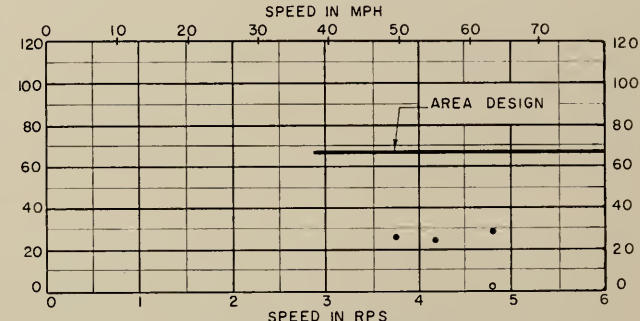
FIG. 71
C.M. ST. P. & P. R.R. BRIDGE TESTS
55'-0 EASTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL o NORTH GIRDER
• SOUTH GIRDER

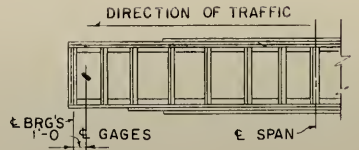
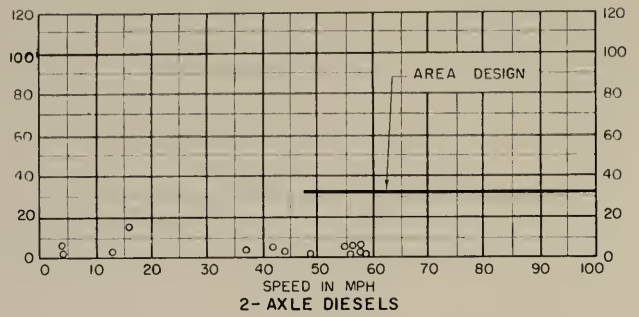
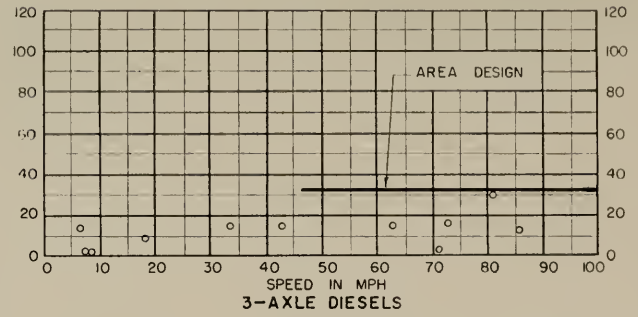


FIG 72
C M ST P & P R R. BRIDGE TESTS
55'-0 WESTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS

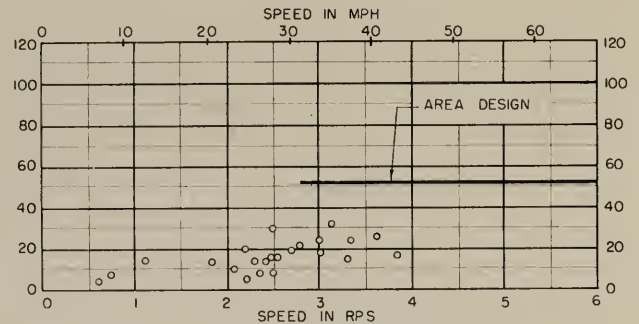


2-AXLE DIESELS

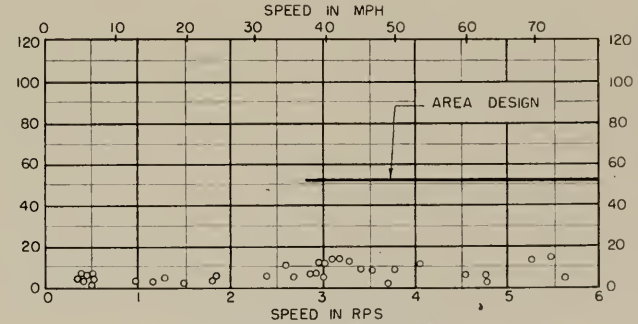


3-AXLE DIESELS

PERCENT OF RECORDED STATIC STRESS



MIKADO 2-8-2, CLASS "L2-b"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL: o NORTH GIRDER

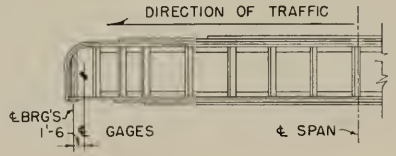


FIG 73
C.M.ST.P.&P.R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS

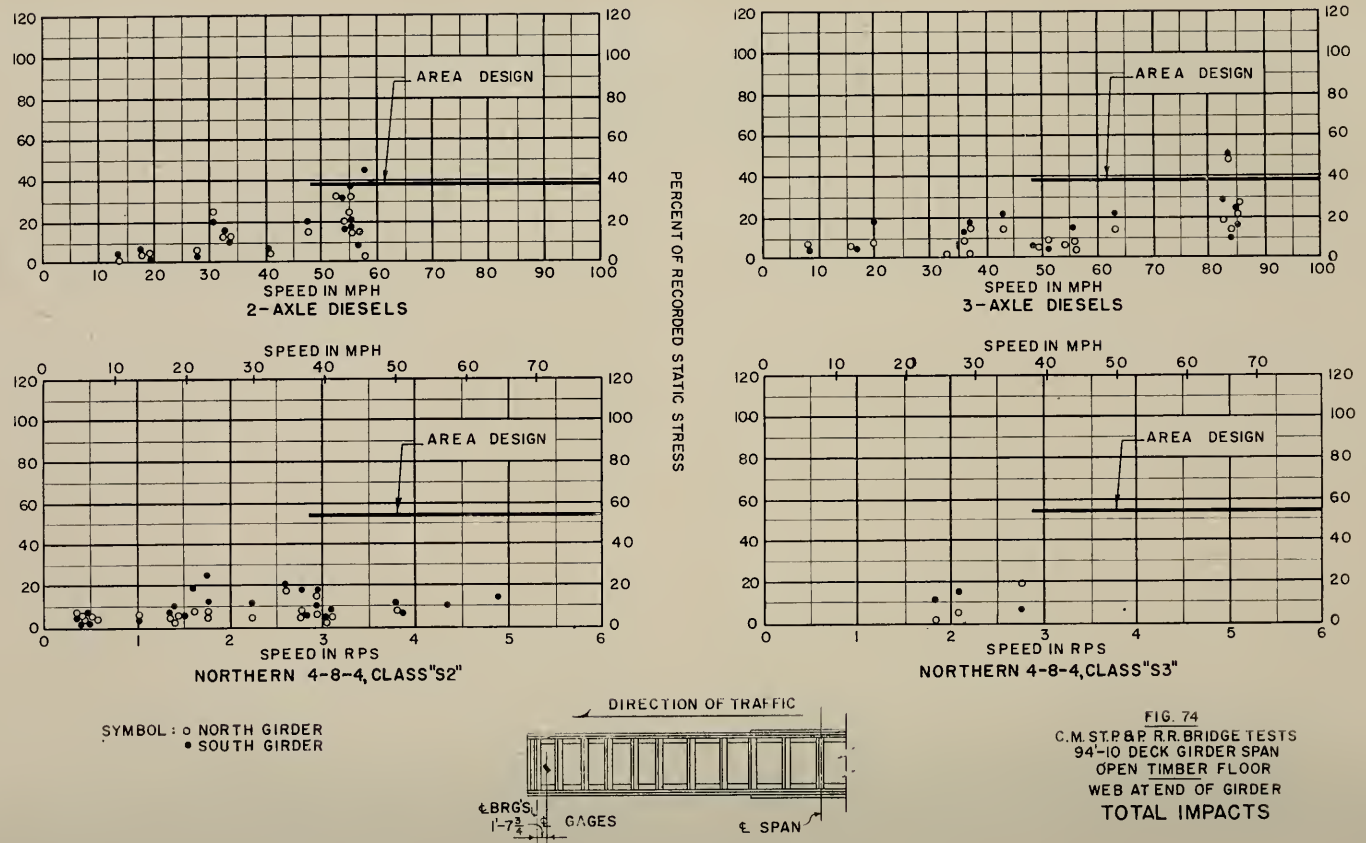
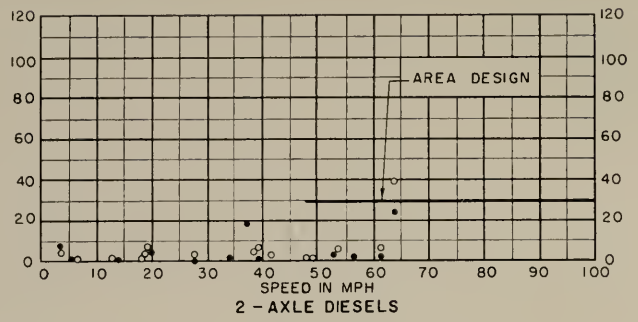
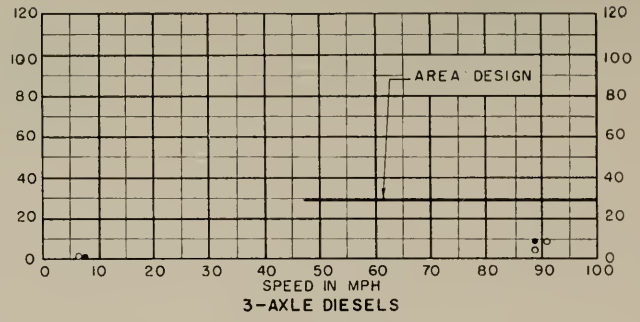
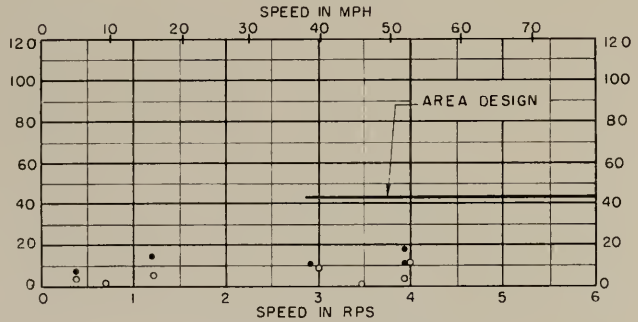


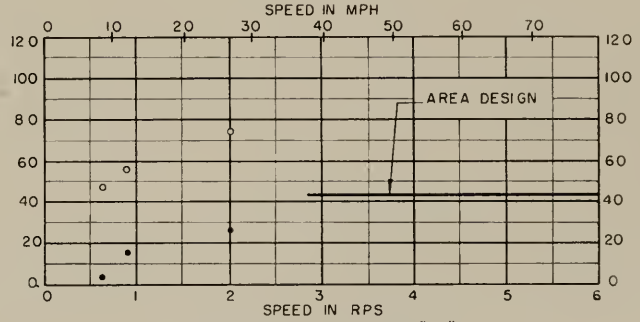
FIG. 74
C.M.ST.P.&P. R.R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

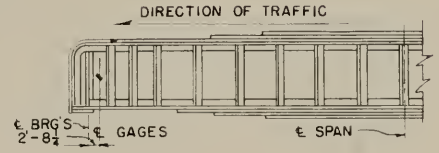
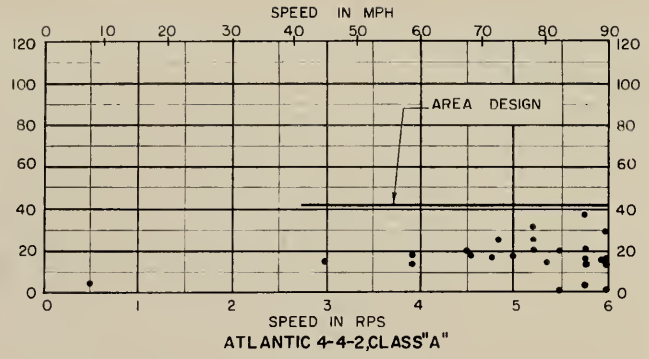
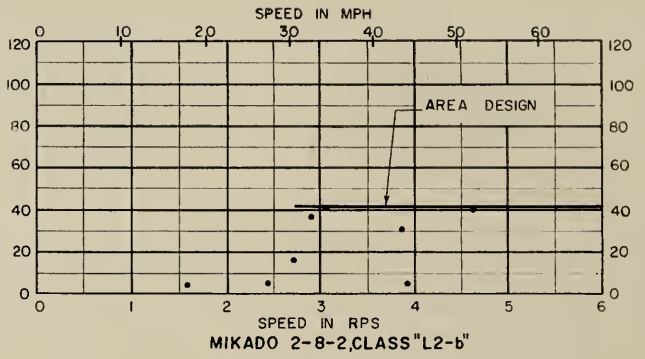
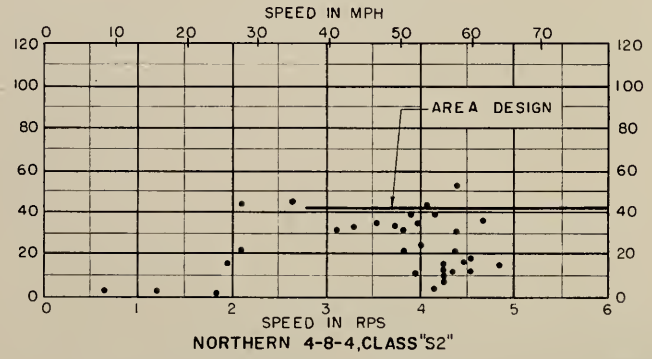
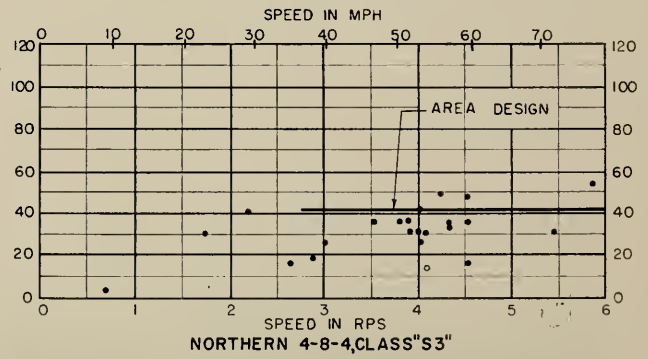


FIG 75
C.M.ST.P.&P.R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS









PERCENT OF RECORDED STATIC STRESS

SYMBOL • SOUTH GIRDER

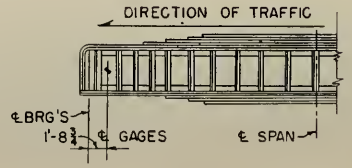
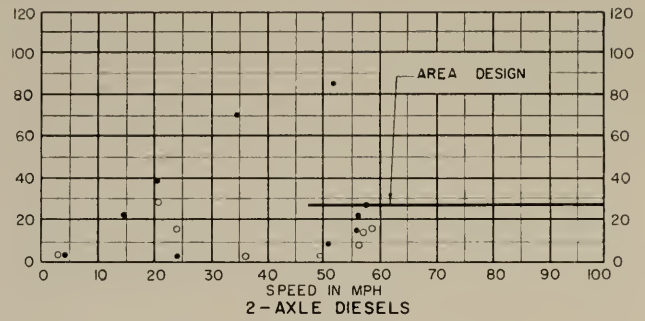
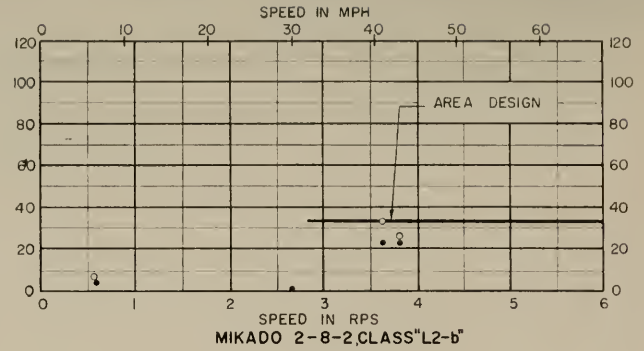
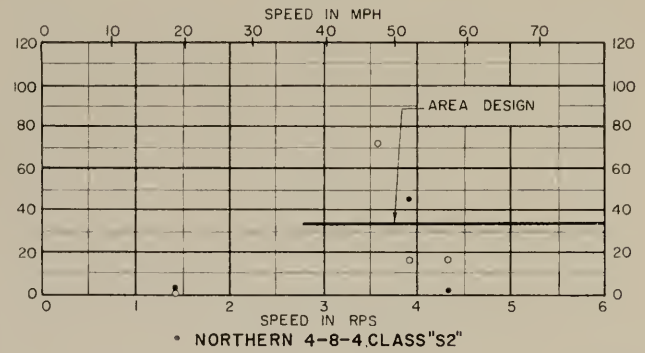


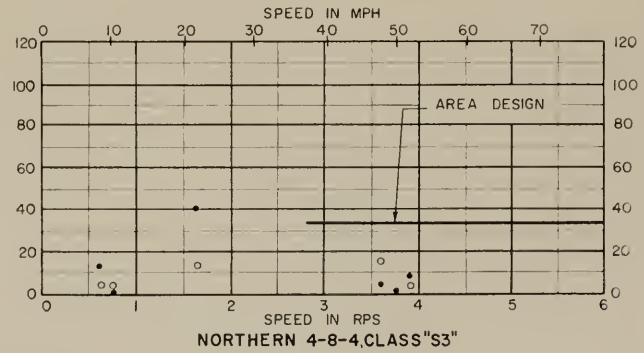
FIG. 76
C.M.ST.P. & P.R.R. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

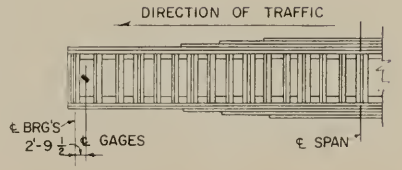
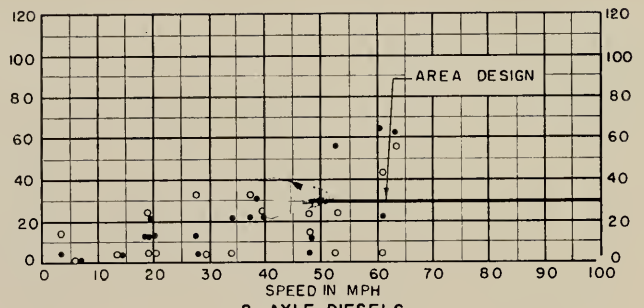
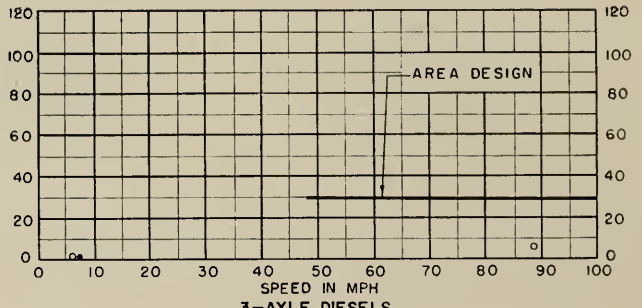
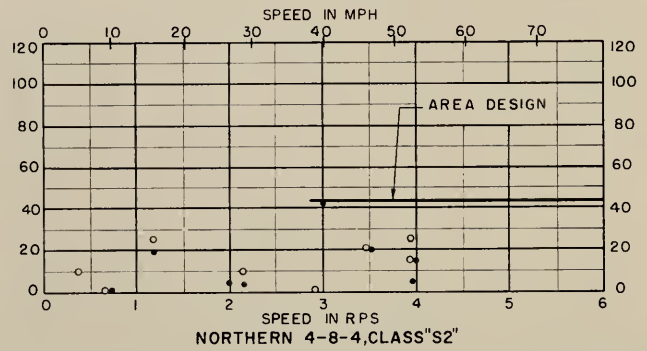


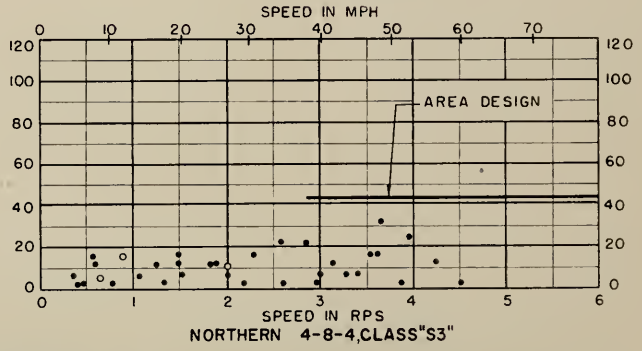
FIG. 77
C.M.ST.P.&P.R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL : o NORTH GIRDER
• SOUTH GIRDER

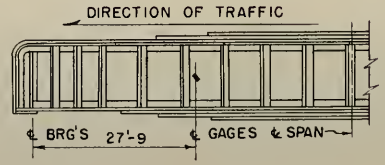
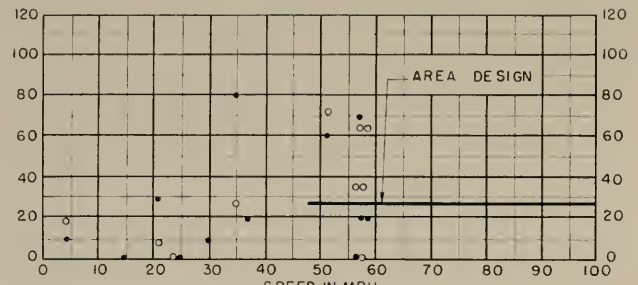
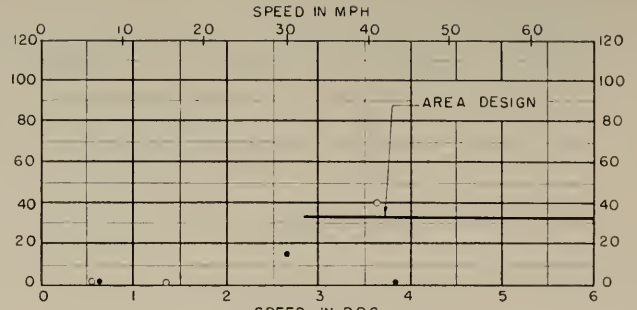
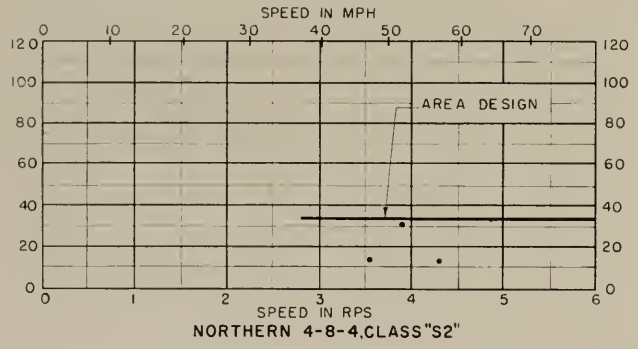


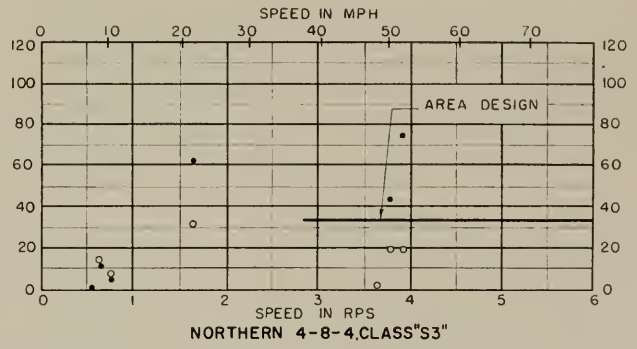
FIG. 78
C. M. ST. P. & P. R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT QUARTER POINT
TOTAL IMPACTS





PERCENT OF RECORDED STATIC STRESS





SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

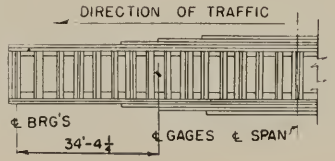
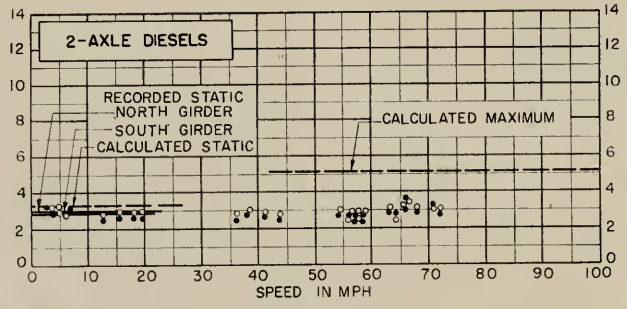
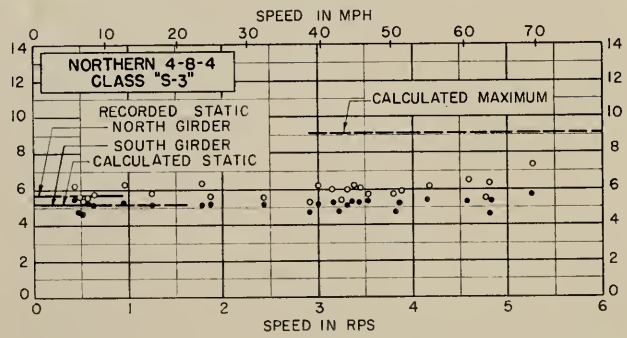
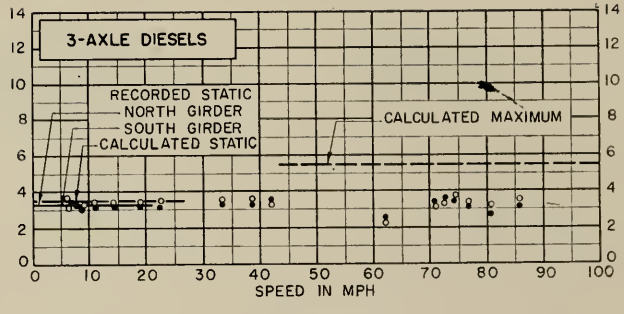


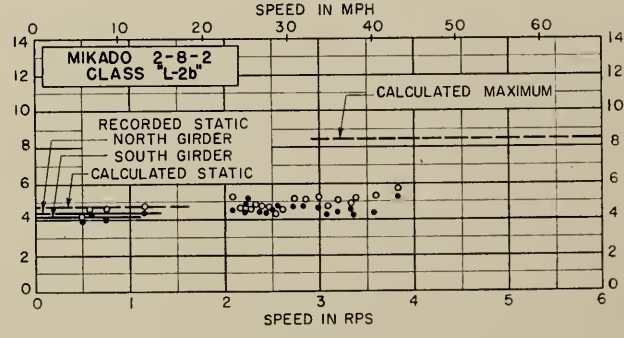
FIG 79
C M ST P & PRR BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT QUARTER POINT
TOTAL IMPACTS





MAXIMUM RECORDED STRESS ON GROSS SECTION (LIVE LOAD PLUS IMPACT)





SYMBOL : ○ NORTH BEAMS
● SOUTH BEAMS

NOTE : CLASS 2-AXLE DIESEL "n" = 8.67 VPS
" 3-AXLE DIESEL "n" = 8.40 VPS
" "L-2b" "n" = 7.65 VPS = 86.2 MPH
" "S3" "n" = 7.00 VPS = 92.5 MPH

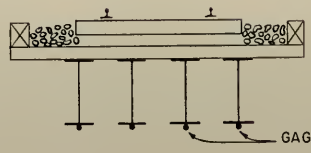
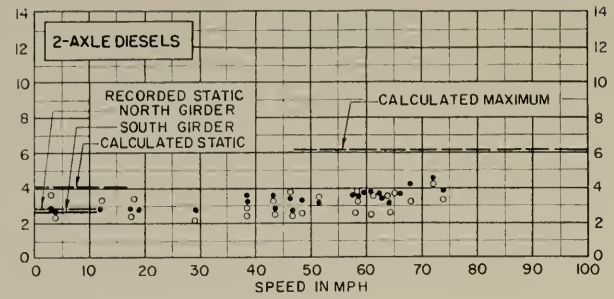
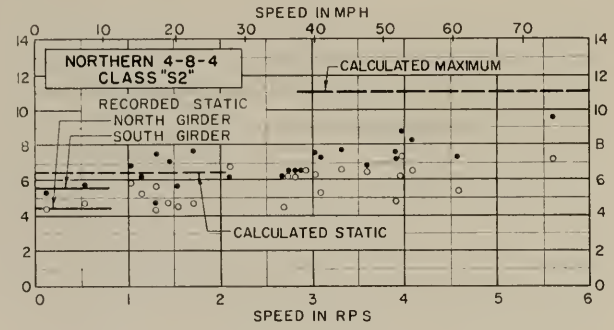
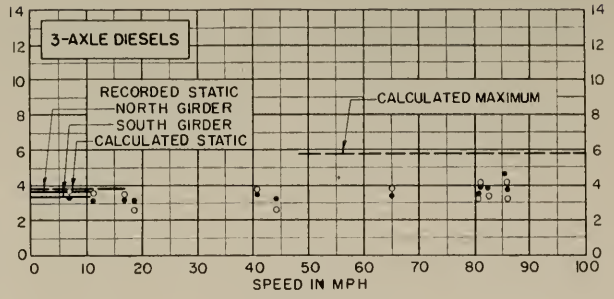


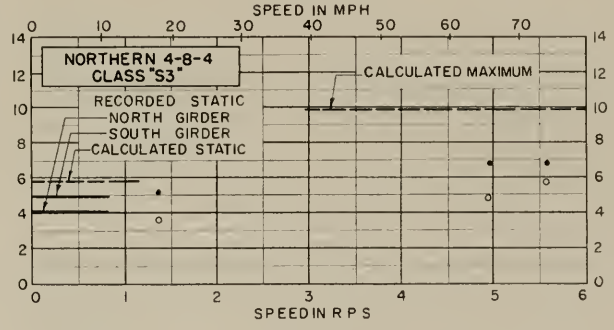
FIG. 80
C.M.ST.P & P.R.R. BRIDGE TESTS
35'-0 WF BEAM SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF BEAMS
MAXIMUM STRESSES
LOCOMOTIVE CLASSES : 2-AXLE & 3-AXLE DIESELS, "S3" & "L-2b"





MAXIMUM RECORDED STRESS ON GROSS SECTION (LIVE LOAD PLUS IMPACT)

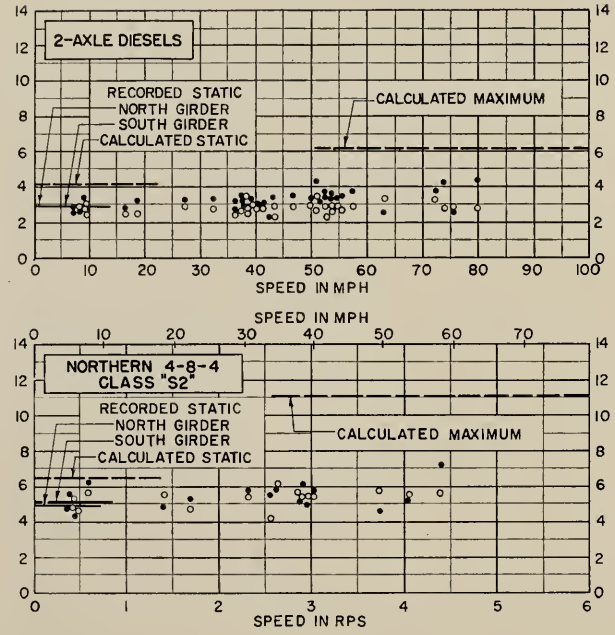




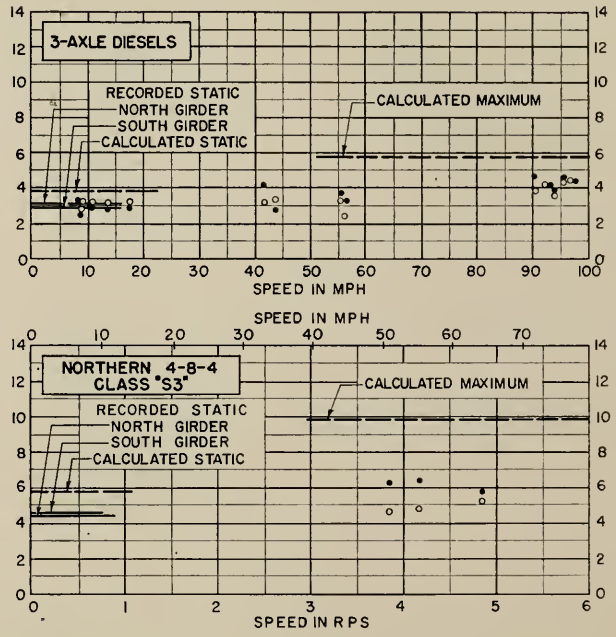
SYMBOL ○ NORTH GIRDER
● SOUTH GIRDER

NOTE: CLASS 2-AXLE DIESEL "n" = 11.18 VPS
" 3-AXLE DIESEL "n" = 10.10 VPS
" "S2" "n" = 8.77 VPS = 115.8 MPH
" "S3" "n" = 9.15 VPS = 120.8 MPH

FIG. 81
C.M.ST P & P R.R BRIDGE TESTS
40'-0 DECK PLATE GIRDER-EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES 2-AXLE & 3-AXLE DIESELS, S2 & S3



MAXIMUM RECORDED STRESS ON GROSS SECTION (LIVE LOAD PLUS IMPACT)



SYMBOL: ○NORTH GIRDER
●SOUTH GIRDER

NOTE: CLASS 2-AXLE DIESEL "n"=11.18 VPS
3-AXLE DIESEL "n"=10.88VPS
"S2" "n"= 8.78 VPS=116.0 M PH
"S3" "n"= 9.15 VPS=120.8 MPH

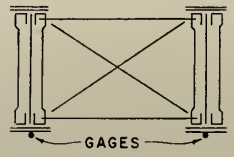
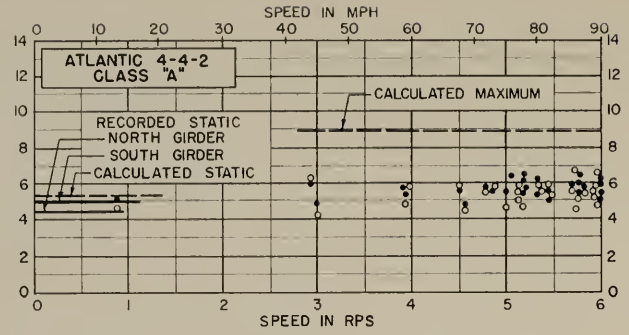
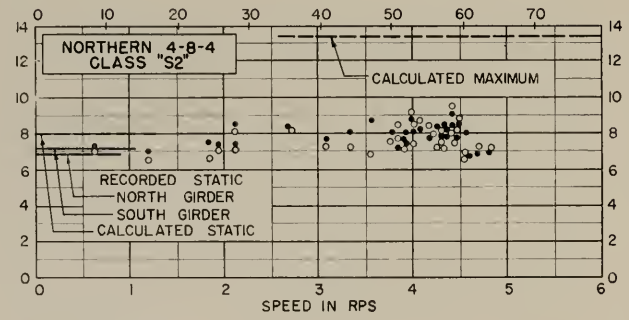
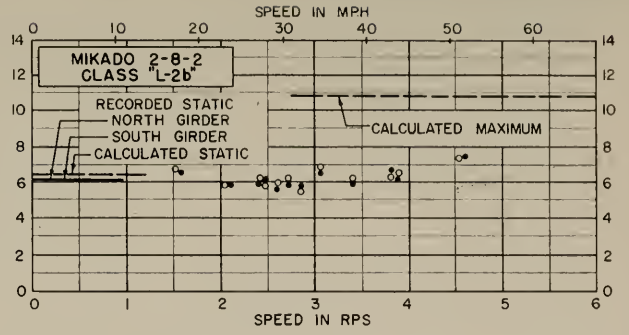


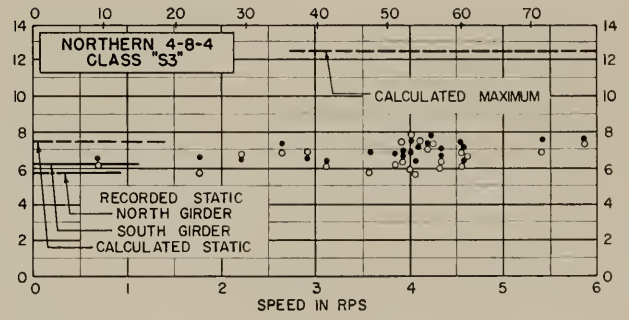
FIG. 82
C.M.ST.P & P. R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, S2 & S3





MAXIMUM RECORDED STRESS ON GROSS SECTION
(LIVE LOAD PLUS IMPACT)





SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

NOTE:
CLASS	"A"	"n" = 7.19	VPS = 107.5	MPH
"	"L2b"	"n" = 6.52	VPS = 73.5	MPH
"	"S2"	"n" = 6.24	VPS = 82.4	MPH
"	"S3"	"n" = 6.60	VPS = 87.2	MPH

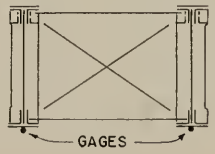
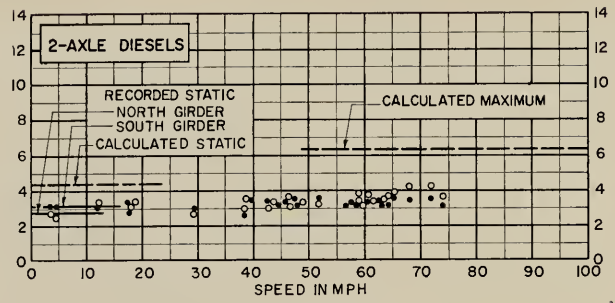
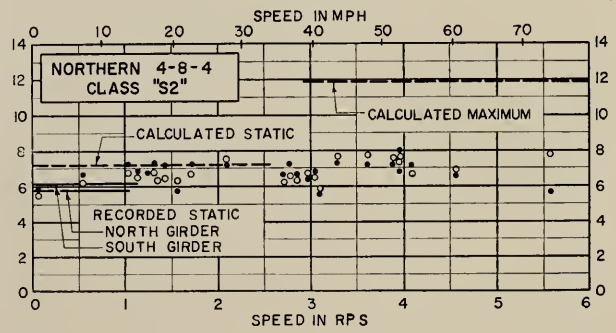
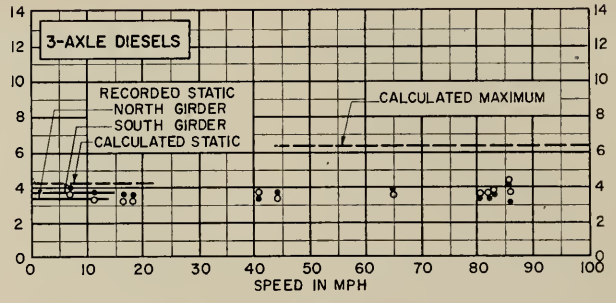


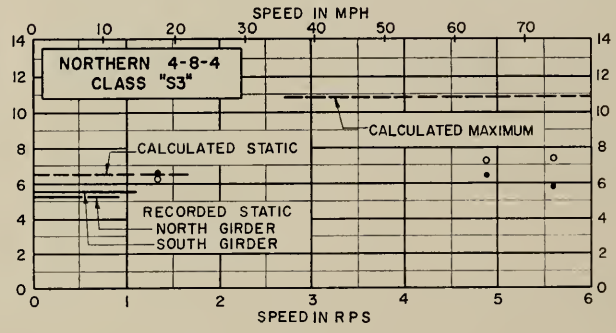
FIG. 83
C.M.ST.P.&P RR. BRIDGE TESTS
46'-8¾ DECK GIRDER SPAN
BALLASTED TIMBER FLOOR.
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASS: "A", "L-2b", "S2" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)





SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

NOTE: CLASS 2-AXLE DIESELS "n" = 8.52 VPS
" 3-AXLE DIESELS "n" = 7.90 VPS
" "S2" "n" = 6.35 VPS = 84.0 MPH
" "S3" "n" = 6.63 VPS = 87.8 MPH

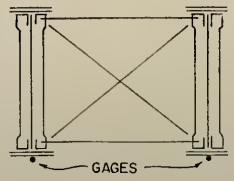
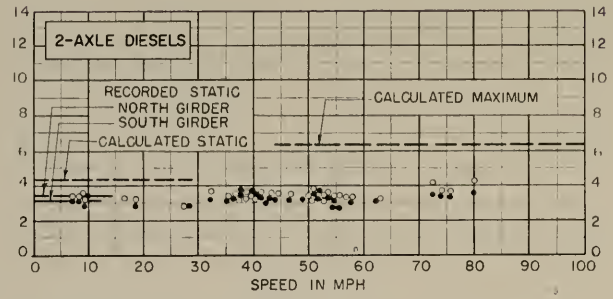
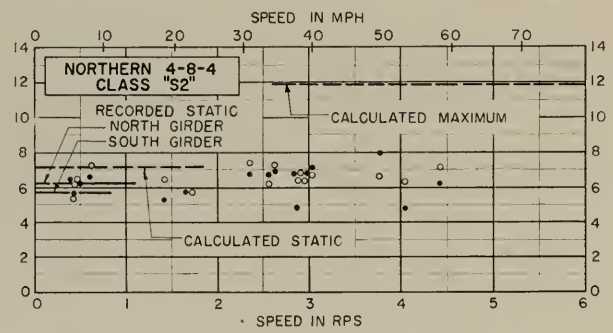
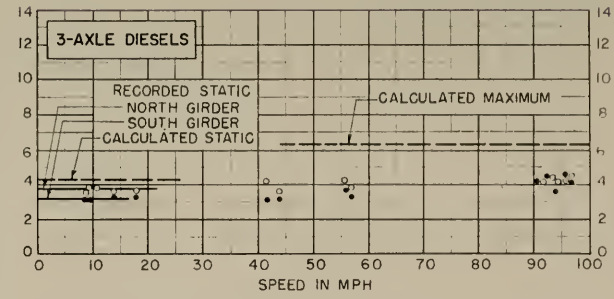


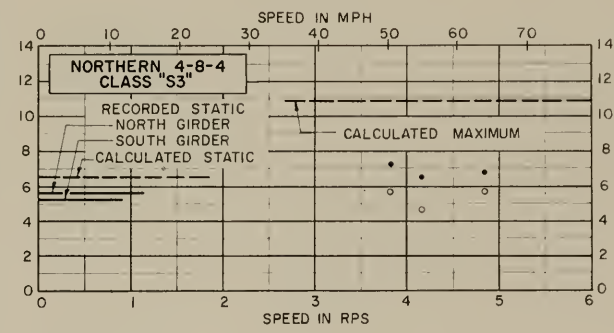
FIG. 84
C.M. ST. P & P. R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER - EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES · 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)





SYMBOL : ○ NORTH GIRDER
● SOUTH GIRDER

NOTE : CLASS 2-AXLE DIESEL "n"= 8.30 VPS
" 3-AXLE DIESEL "n"= 8.02 VPS
" "S2" "n"= 6.35 VPS = 84.0 MPH
" "S3" "n"= 6.63 VPS = 87.8 MPH

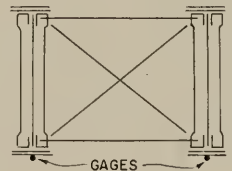
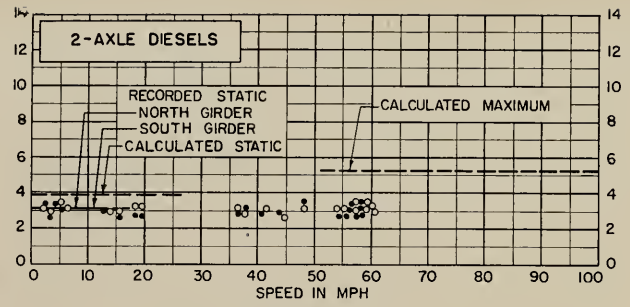
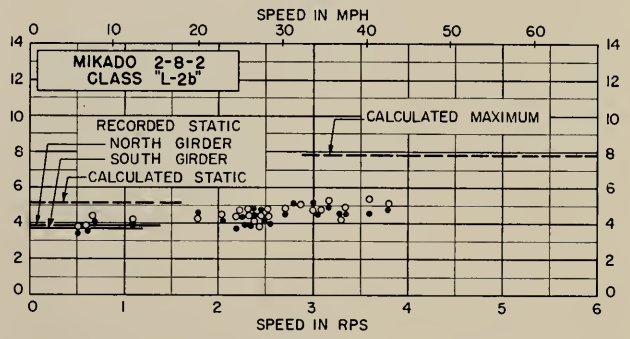
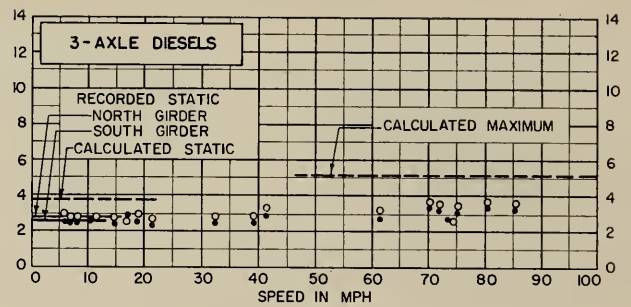


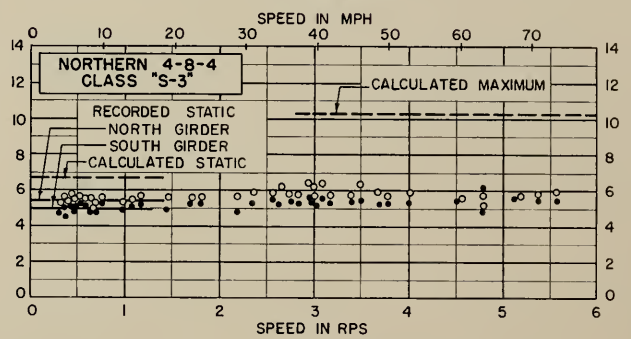
FIG. 85
C.M.ST P&P R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES : 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION
(LIVE LOAD PLUS IMPACT)





SYMBOL: o NORTH GIRDER
• SOUTH GIRDER

NOTE: CLASS 2-AXLE DIESELS "n" = 5.61 VPS
" 3-AXLE DIESELS "n" = 5.78 VPS
" "L-2b" "n" = 5.24 = 59.0 MPH
" "S3" "n" = 4.76 = 62.9 MPH

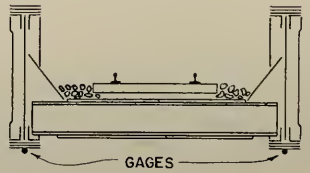
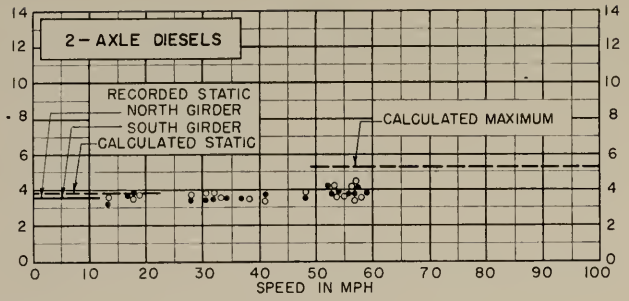
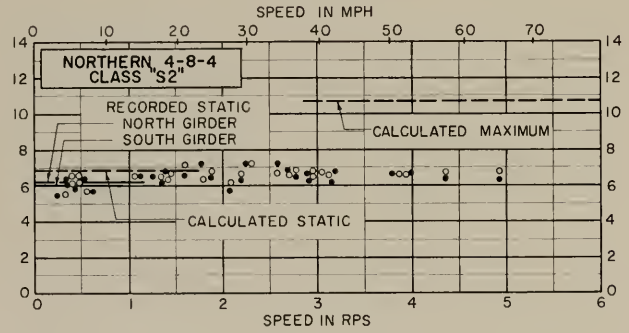
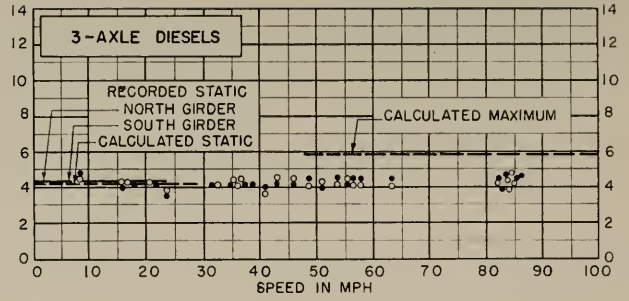


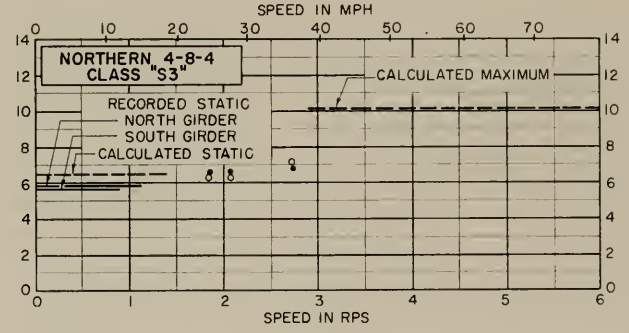
FIG. 86
C.M.ST.P.&P. R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "L-2b" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION (LIVE LOAD PLUS IMPACT)





SYMBOL : o NORTH GIRDER
• SOUTH GIRDER

NOTE : CLASS 2-AXLE DIESELS "n"= 5.24 VPS
" 3-AXLE DIESELS "n"= 4.75 VPS
" "S2" "n"= 4.23 VPS = 55.8 MPH
" "S3" "n"= 4.33 VPS = 57.2 MPH

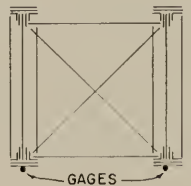
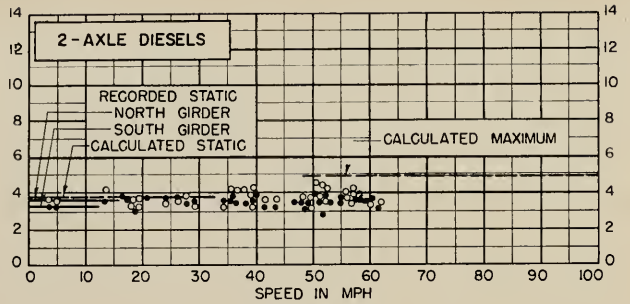
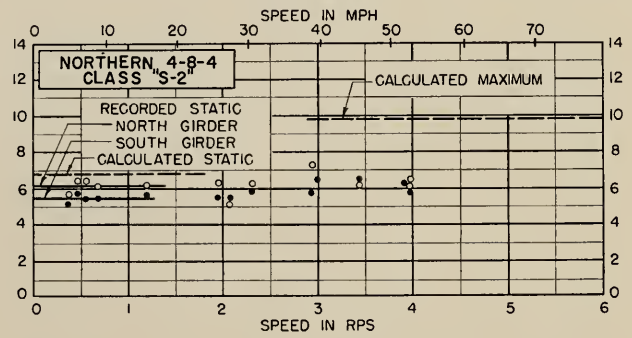
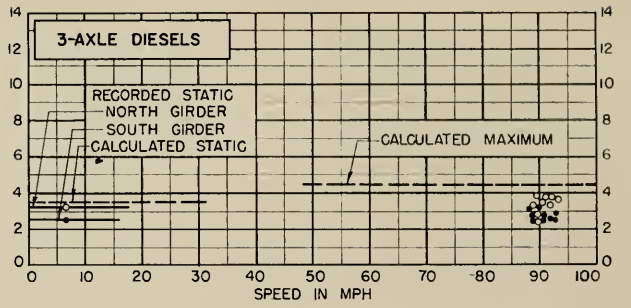


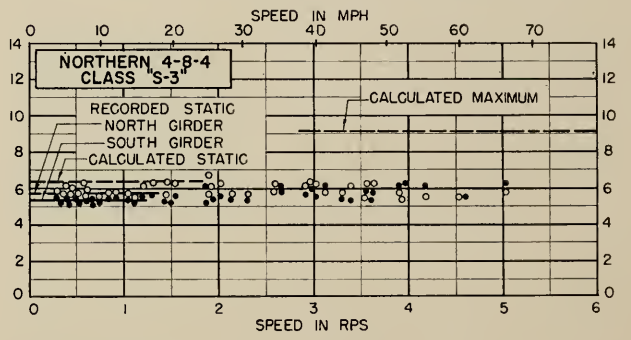
FIG. 87
C.M.ST.P & P.R.R BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION (LIVE LOAD PLUS IMPACT)





SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

NOTE: CLASS 2-AXLE DIESELS "n" = 4.37 VPS
3-AXLE DIESELS "n" = 4.58 VPS
"S2" "n" = 3.78 VPS = 49.8 MPH
"S3" "n" = 3.83 VPS = 50.6 MPH

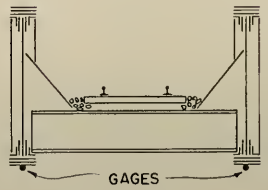
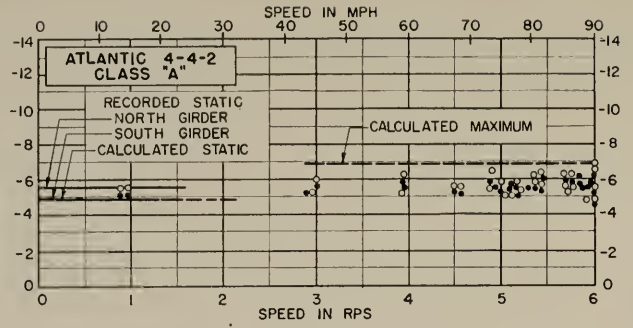
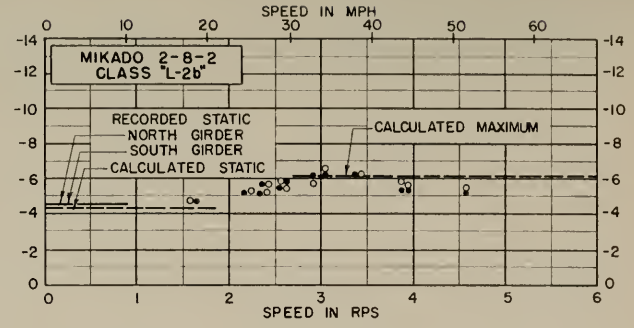
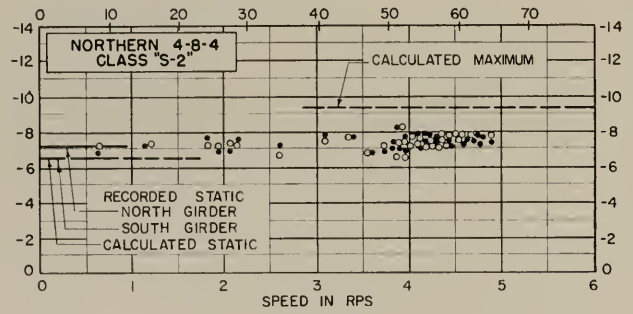
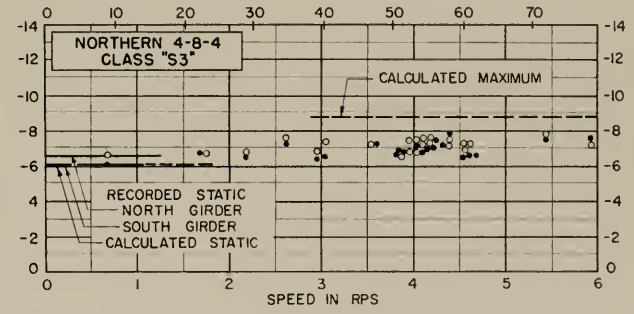


FIG. 88
C.M. ST. P. & P. R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASSES: 2-AXLE & 3-AXLE DIESELS, "S2" & "S3"









MAXIMUM RECORDED STRESS ON GROSS SECTION
(LIVE LOAD PLUS IMPACT)

SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

NOTE : CLASS "A" "n" = 3.74 VPS = 560 MPH
" "L-2b" "n" = 3.90 VPS = 440 MPH
" "S2" "n" = 3.44 VPS = 455 MPH
" "S3" "n" = 3.53 VPS = 466 MPH

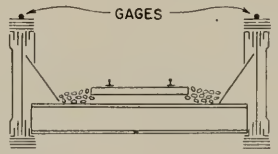
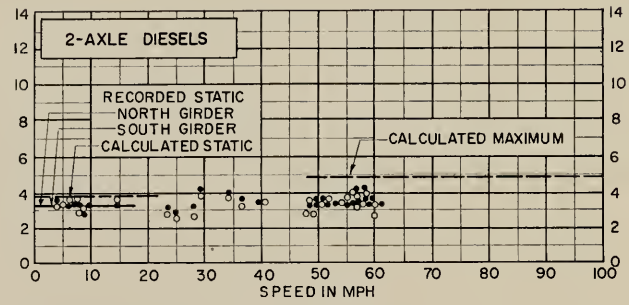
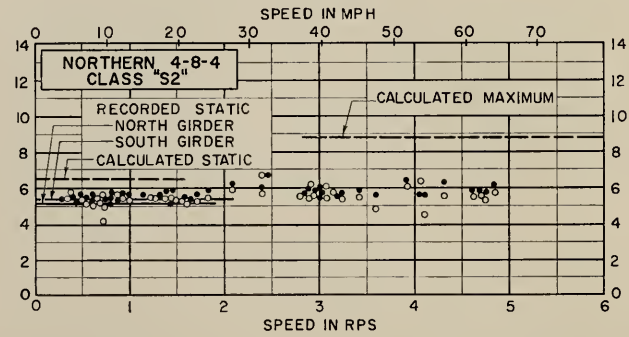
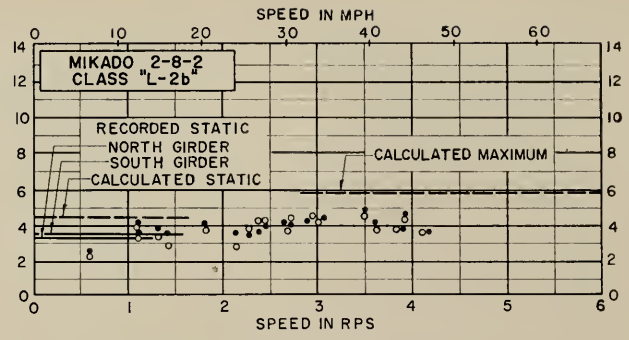


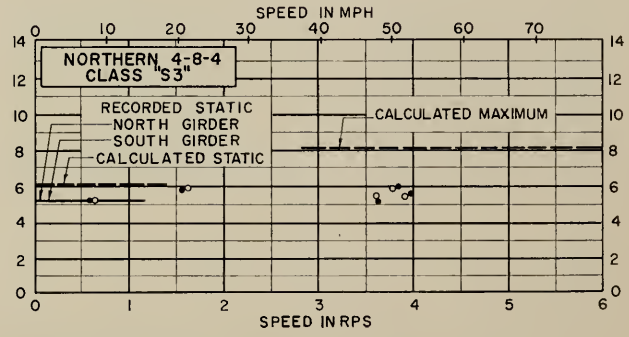
FIG. 89
C.M.ST.P.&P.R.R. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASS: "A", "L-2b", "S2" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION
(LIVE LOAD PLUS IMPACT)





SYMBOL: ○ NORTH GIRDER
• SOUTH GIRDER

NOTE : CLASS 2-AXLE DIESEL "n"=3.77 VPS
" "L2-b" "n"=3.80 VPS = 42.9 MPH
" "S2" "n"=3.29 VPS = 43.5 MPH
" "S3" "n"=3.33 VPS = 44.0 MPH

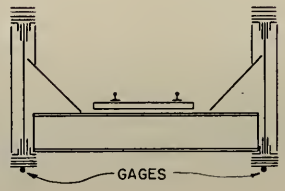
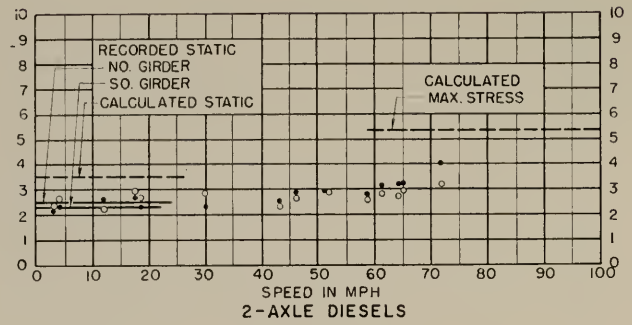
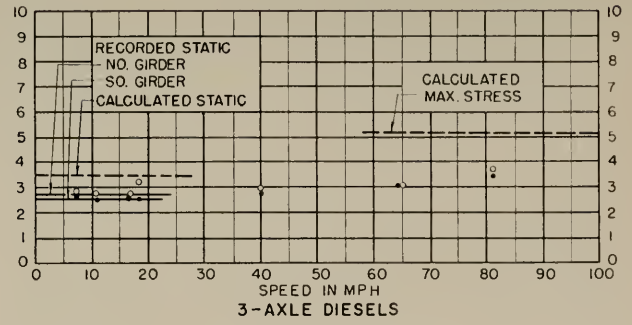
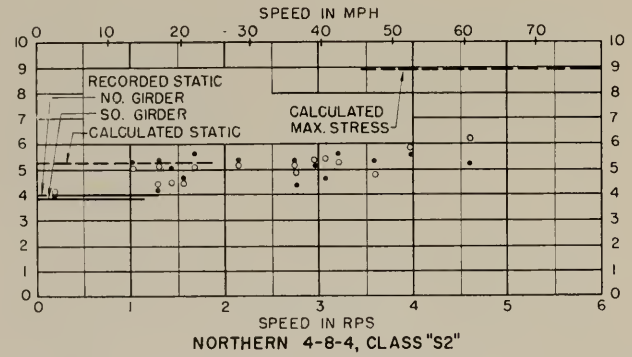


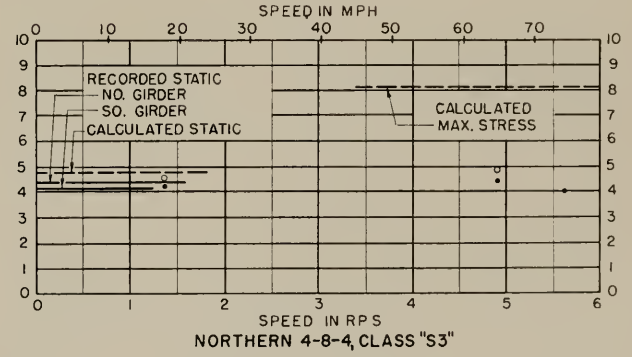
FIG. 90
C.M.ST.P.&P.R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
MAXIMUM STRESSES
LOCOMOTIVE CLASS: 2-AXLE DIESEL, "L-2b", "S2" & "S3"





MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI (LIVE LOAD PLUS IMPACT)





SYMBOL : ○ NORTH GIRDER
• SOUTH GIRDER

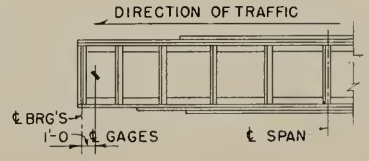
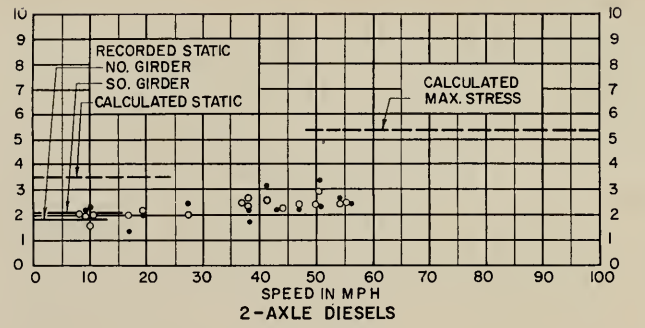
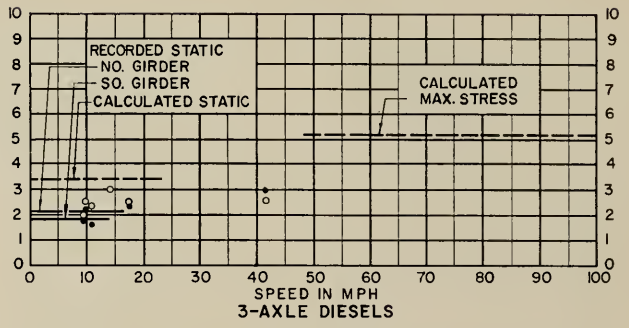
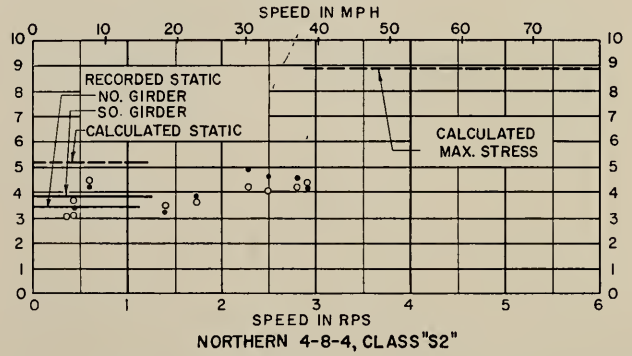


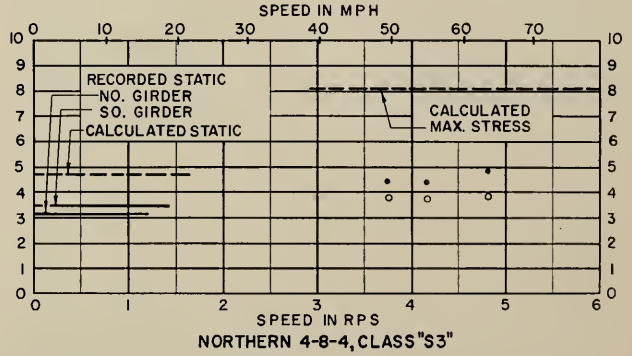
FIG. 91
C. M. ST. P. & P. R. R. BRIDGE TESTS
40'-0 EASTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES





MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)





SYMBOL : o NORTH GIRDER
• SOUTH GIRDER

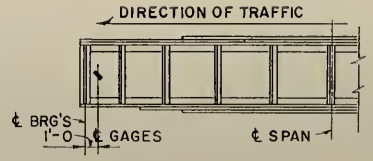
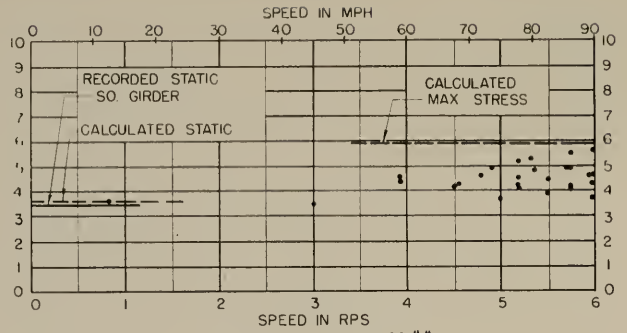
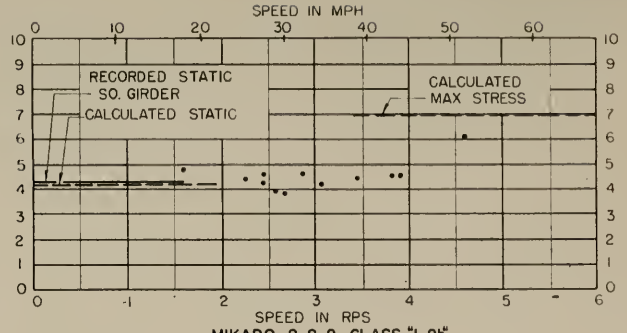


FIG. 92
C.M.ST.P. &P.R.R. BRIDGE TESTS
40'-0 WESTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

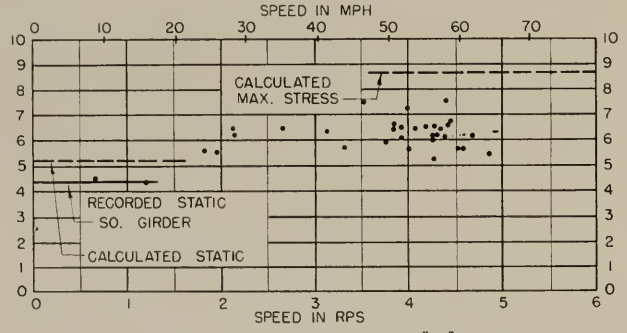


ATLANTIC 4-4-2, CLASS "A"

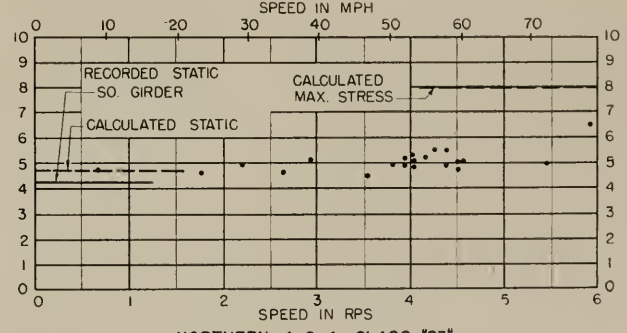


MIKADO 2-8-2, CLASS "L-25"

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI (LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL. • SOUTH GIRDER

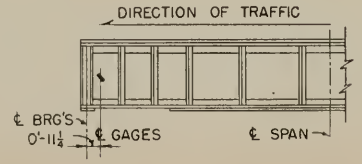
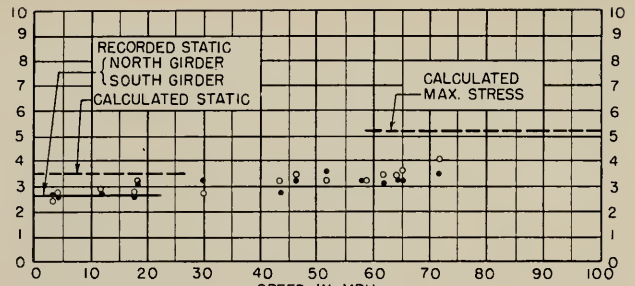
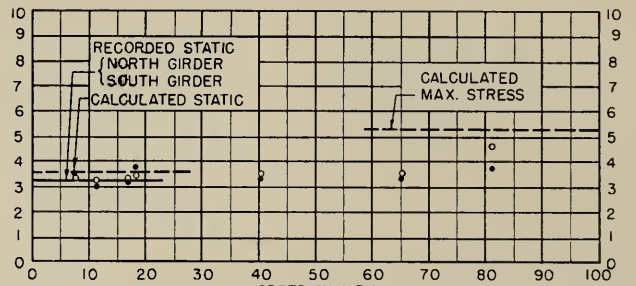


FIG. 93
C.M.ST.P&P.RR. BRIDGE TESTS
46'-8¾ DECK GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

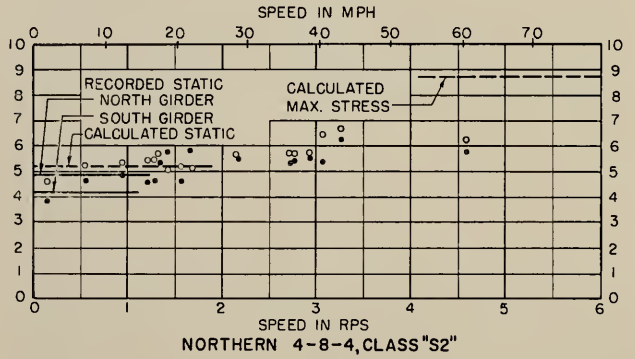


2-AXLE DIESELS

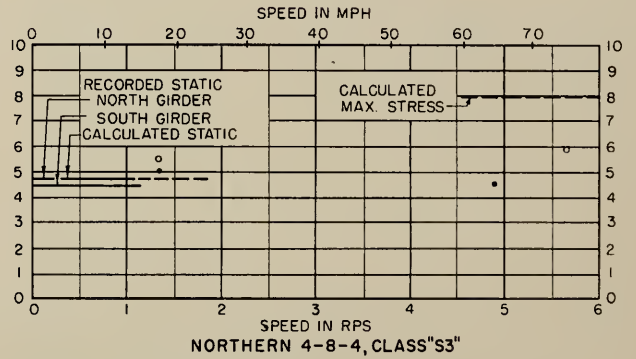


3-AXLE DIESELS

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL : ○ NORTH GIRDER
● SOUTH GIRDER

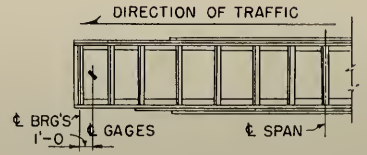
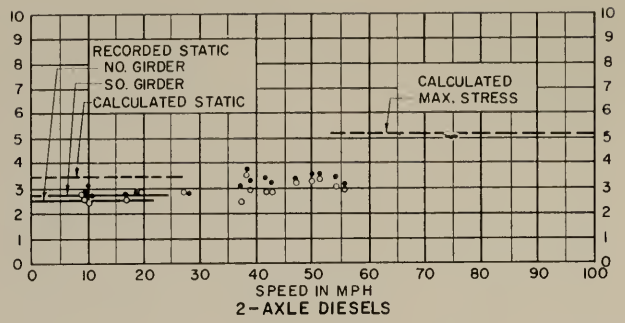
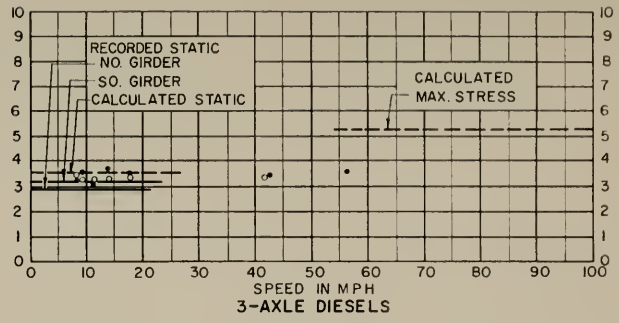


FIG 94
C.M.ST.P.&P.R.R. BRIDGE TESTS
55'-0 EASTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

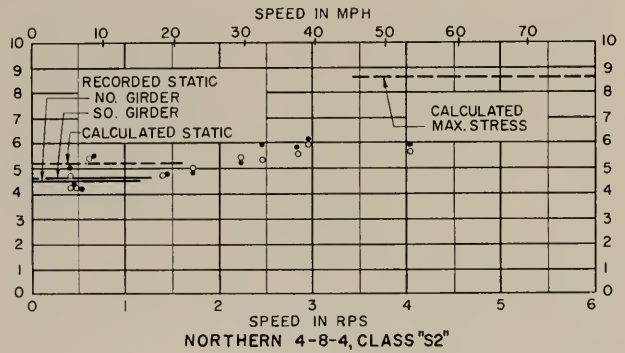


2-AXLE DIESELS

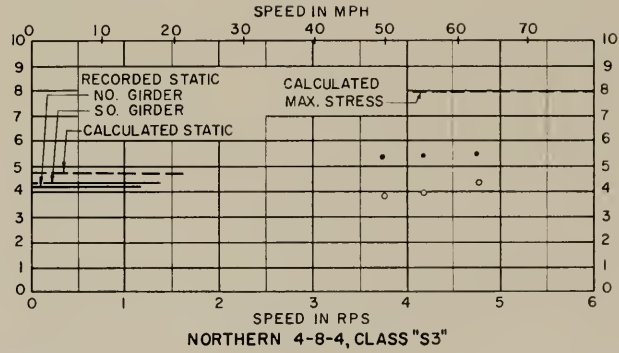


3-AXLE DIESELS

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL : ○ NORTH GIRDER
● SOUTH GIRDER

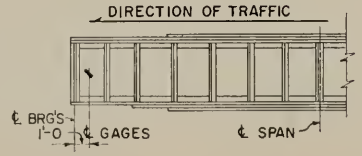
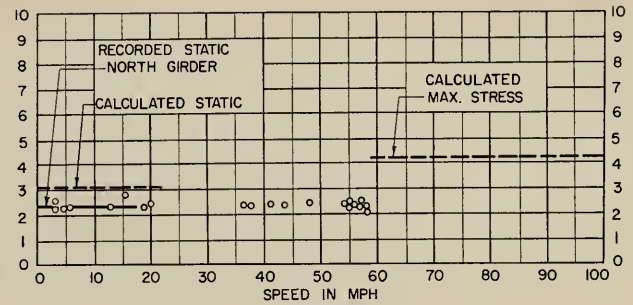
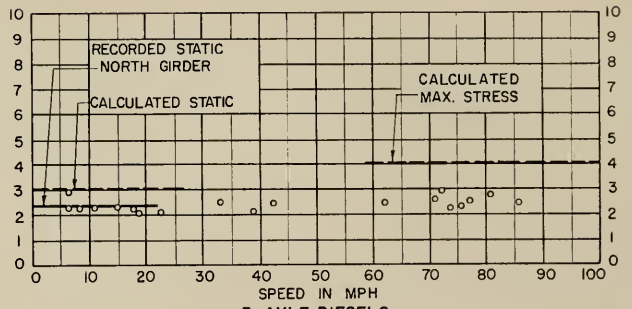


FIG. 95
C. M. ST. P & P. R.R. BRIDGE TESTS
55'-0 WESTBOUND DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

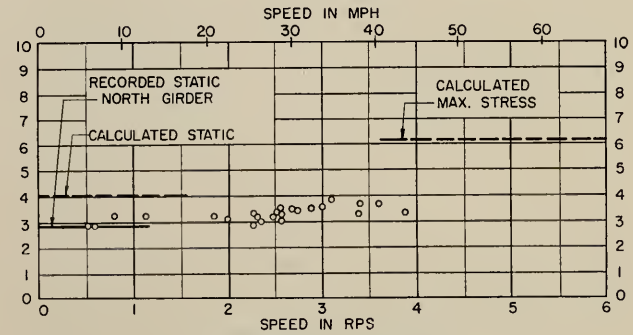


2-AXLE DIESELS

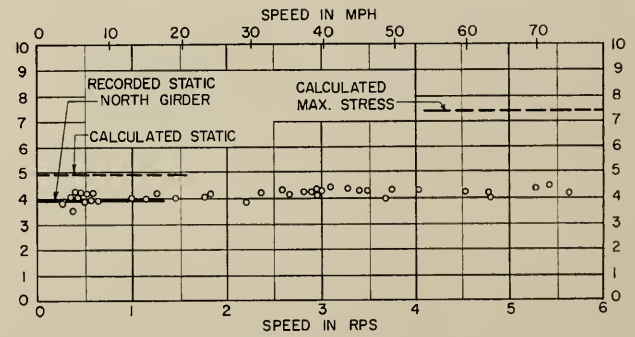


3-AXLE DIESELS

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)



MIKADO 2-8-2, CLASS "L-2b"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL o NORTH GIRDER

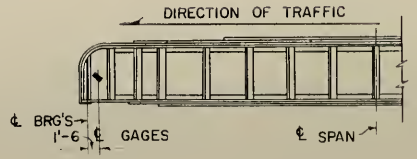
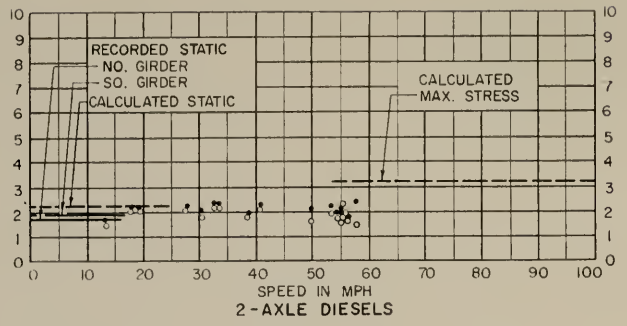
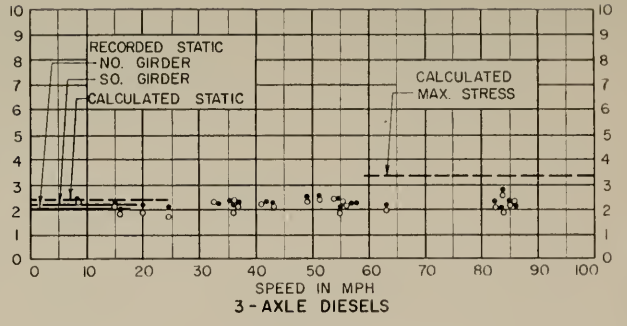


FIG. 96
C.M.ST.P.&P.R.R. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER
WEB AT END OF GIRDER
MAXIMUM STRESSES

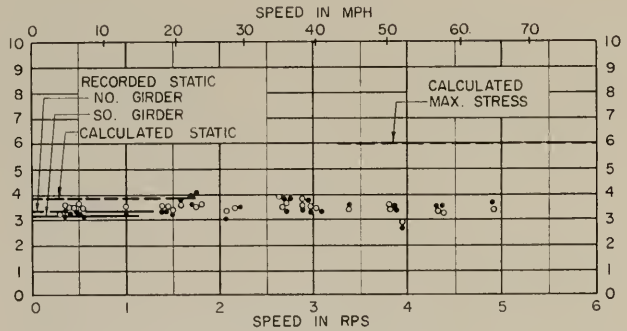


2-AXLE DIESELS

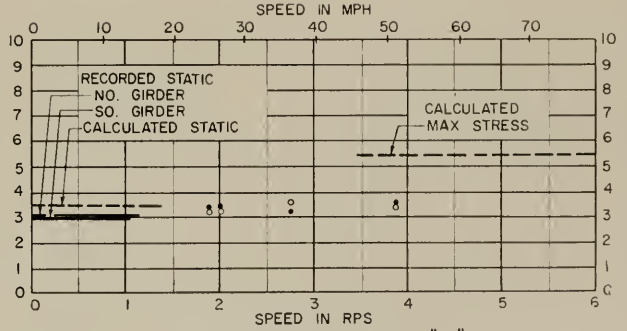


3-AXLE DIESELS

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

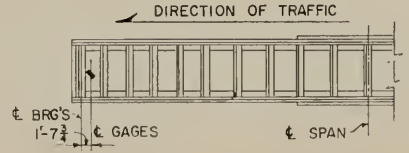
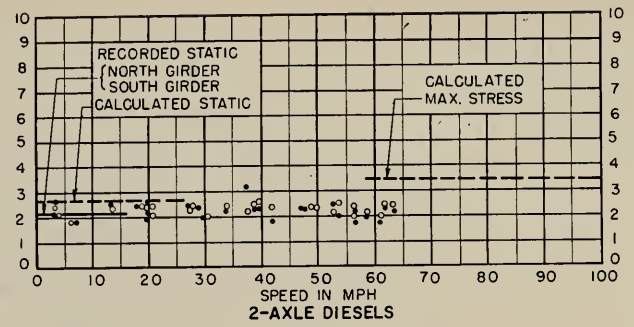
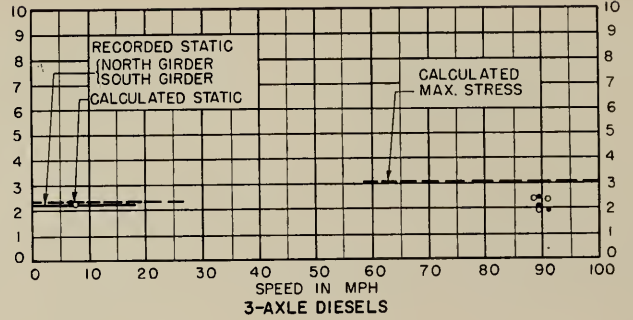


FIG. 97
C.M.ST.P.&P.R.R. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

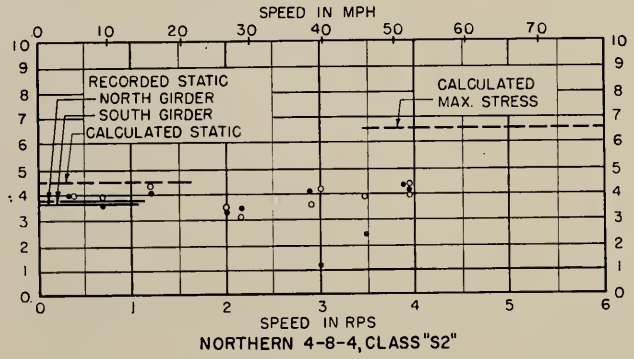


2-AXLE DIESELS

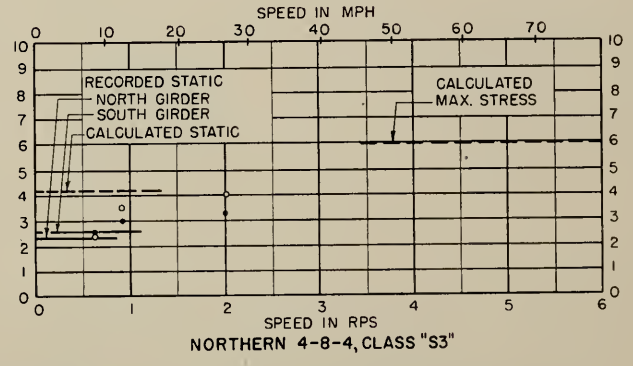


3-AXLE DIESELS

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL : ○ NORTH GIRDER
● SOUTH GIRDER

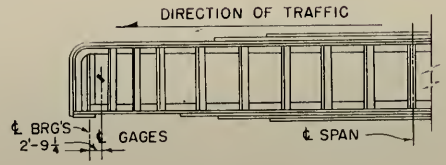
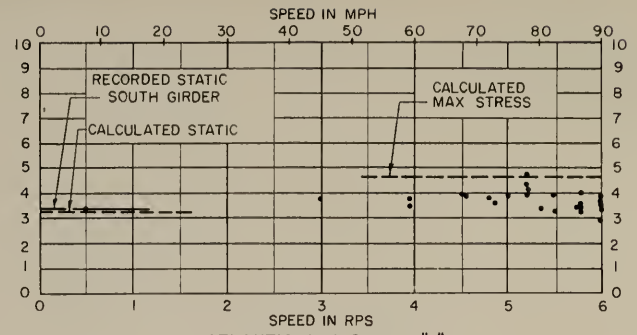
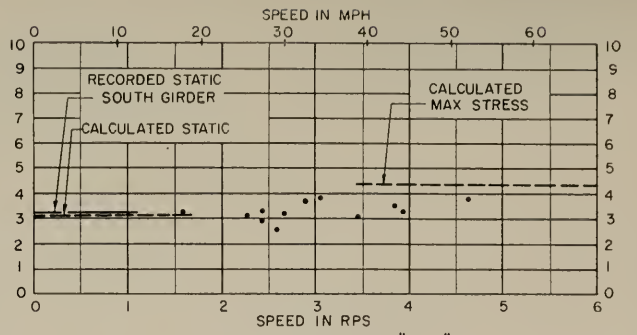


FIG. 98
C M ST. P & P R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

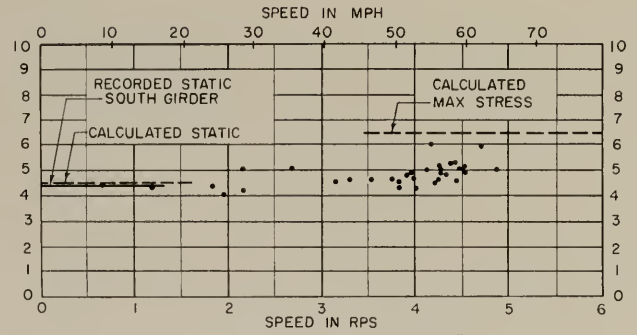


ATLANTIC 4-4-2, CLASS "A"

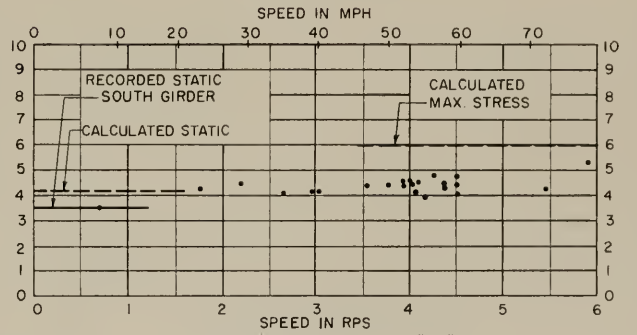


MIKADO 2-8-2, CLASS "L-2b"

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI (LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL • SOUTH GIRDER

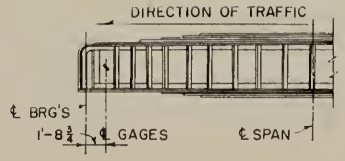
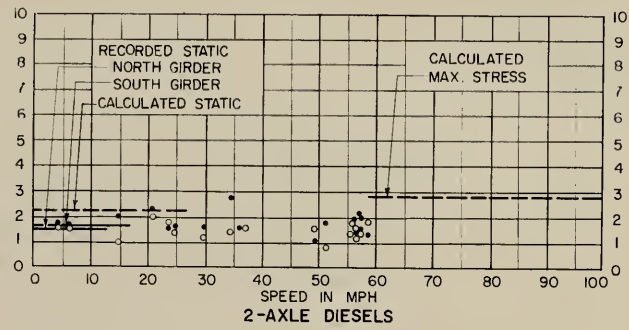
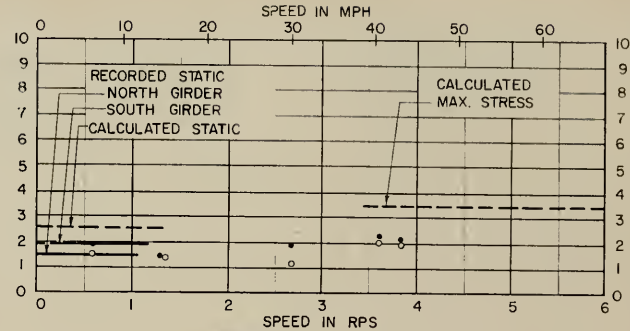


FIG 99
C. M. ST. P. & P. R.R. BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES

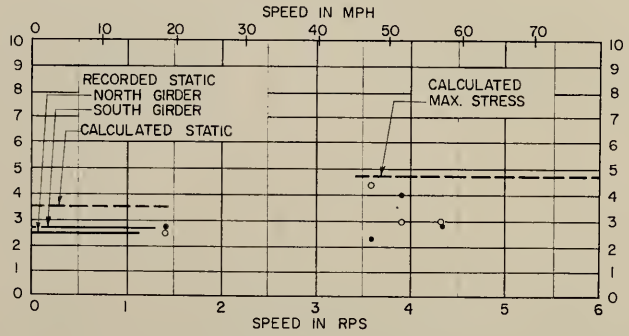


2-AXLE DIESELS

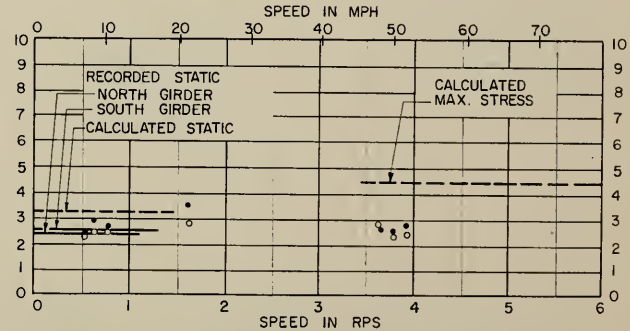


MIKADO 2-8-2, CLASS "L-2b"

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

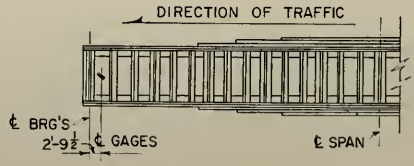
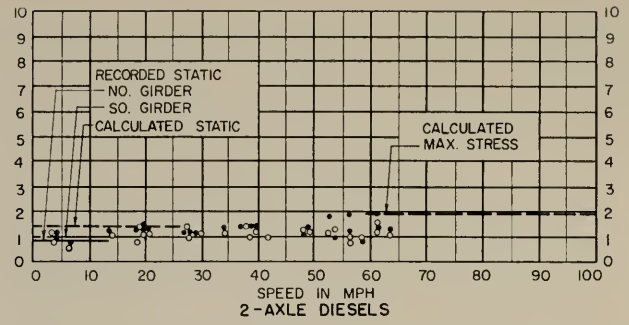
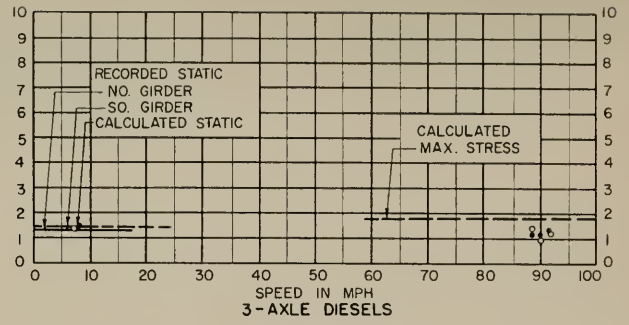
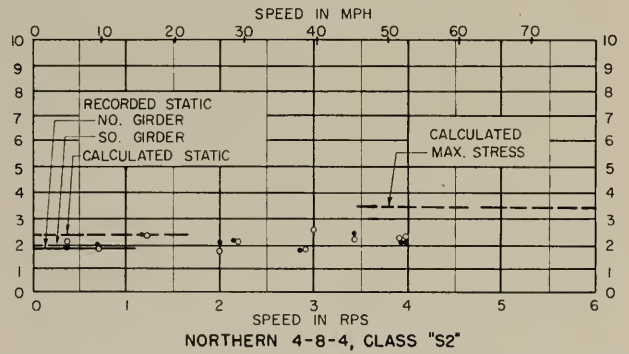


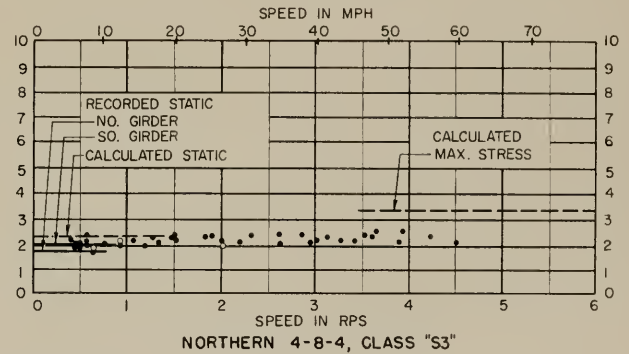
FIG. 100
C.M.ST.P.&P. R.R. BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT END OF GIRDER
MAXIMUM STRESSES





MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)





SYMBOL: ○ NORTH GIRDER
● SOUTH GIRDER

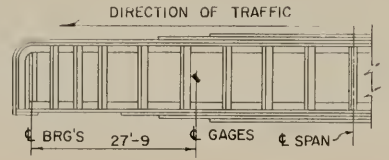
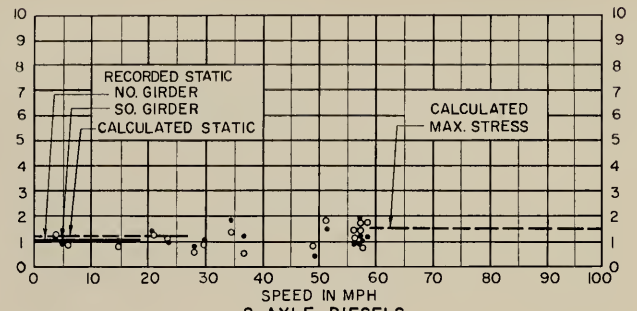
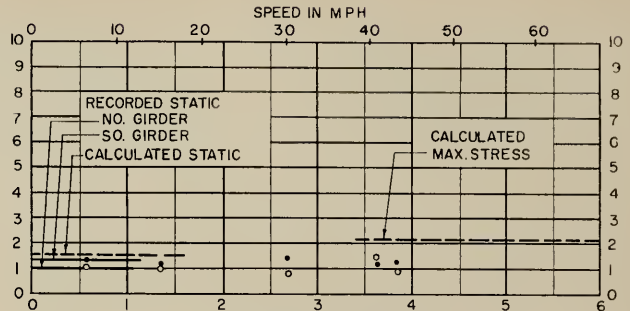


FIG. 101
C.M.ST.P.&P.R.R. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
WEB AT QUARTER POINT
MAXIMUM STRESSES

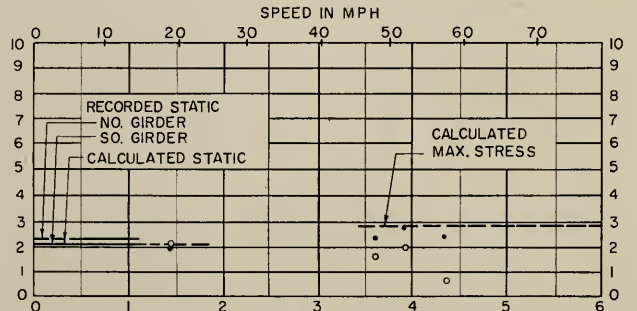


2-AXLE DIESELS

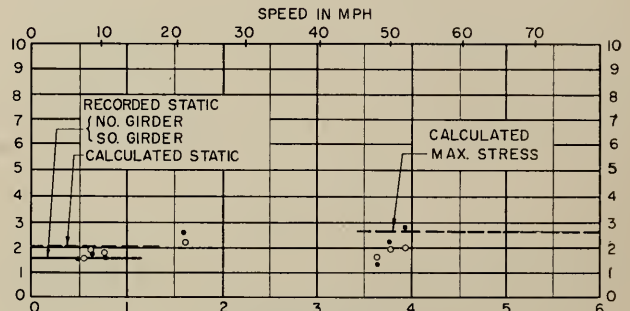


MIKADO 2-8-2, CLASS "L-2b"

MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI (LIVE LOAD PLUS IMPACT)



NORTHERN 4-8-4, CLASS "S2"



NORTHERN 4-8-4, CLASS "S3"

SYMBOL : ○ NORTH GIRDER
• SOUTH GIRDER

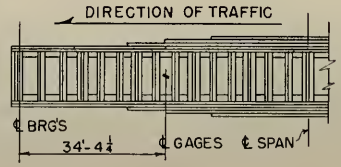
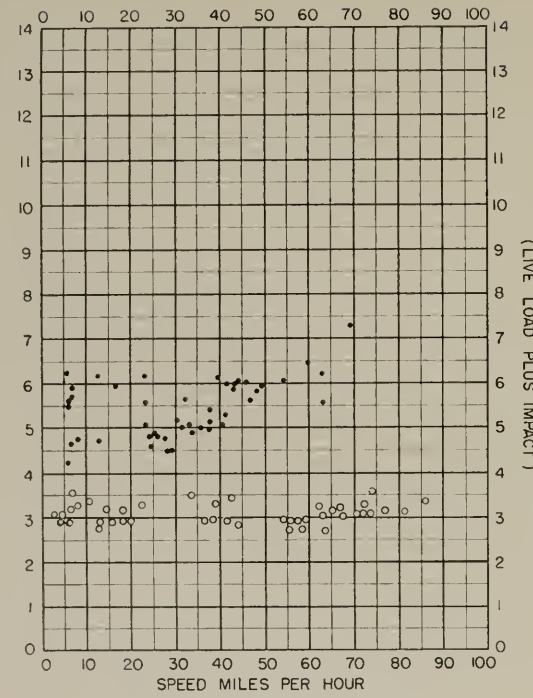


FIG. 102
C.M.ST.P.&P. RR BRIDGE TESTS
140'-0 THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
WEB AT QUARTER POINT
MAXIMUM STRESSES

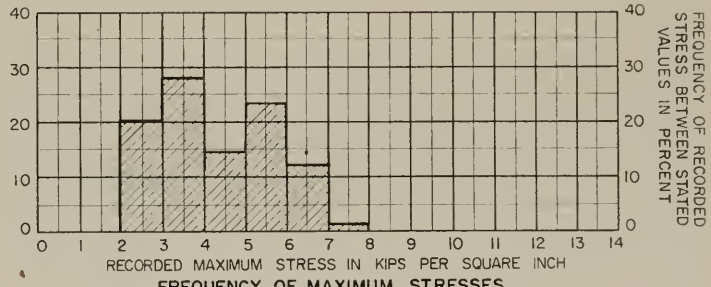


RECORDED MAXIMUM STRESSES
(NORTH BEAMS)

SYMBOL • STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION

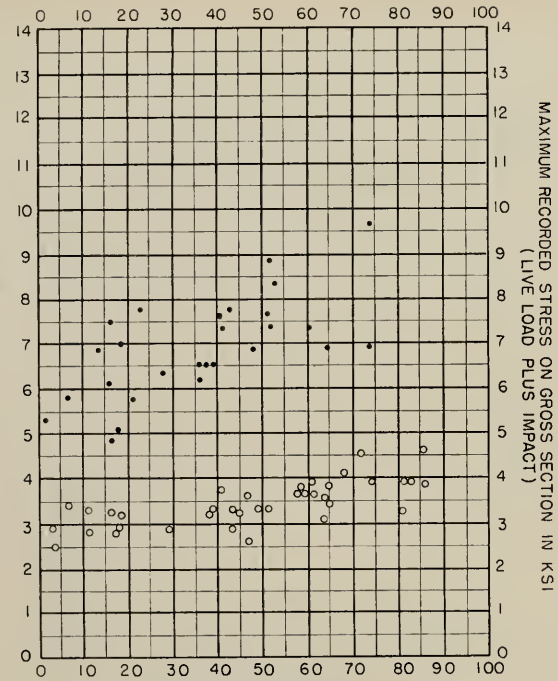
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S3	L2b		2 AXLE	3 AXLE	S3	L2b	
7.0 TO 8.0			1		1			1.1		1.1
6.0 " 7.0			11		11			12.4		12.4
5.0 " 6.0			13	8	21			14.6	9.0	23.6
4.0 " 5.0				13	13				14.6	14.6
3.0 " 4.0	8	17			25	9.0	19.1			28.1
2.0 " 3.0	18				18	20.2				20.2
TOTAL READINGS	26	17	25	21	89	29.2	19.1	28.1	23.6	100.0



FREQUENCY OF MAXIMUM STRESSES
(NORTH BEAMS)

FIG. 103
C.M.ST.P&P R.R. BRIDGE TESTS
35'-0 WF BEAM SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF BEAMS

FREQUENCY OF MAXIMUM STRESSES
NORTH BEAMS


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(SOUTH GIRDER)
SYMBOL • STEAM LOCOMOTIVES
o DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S2	S3		2 AXLE	3 AXLE	S2	S3	
9.0 TO 10.0			1		1			1.6		1.6
8.0 " 9.0			2		2			3.1		3.1
7.0 " 8.0			9		9			14.0		14.0
6.0 " 7.0			8	2	10			12.5	3.1	15.6
5.0 " 6.0			3	1	4			4.7	1.6	6.3
4.0 " 5.0	2	1	1		4	3.1	1.6	1.6		6.3
3.0 " 4.0	15	11			26	23.4	17.2			40.6
2.0 " 3.0	8				8	12.5				12.5
TOTAL READINGS	25	12	24	3	64	39.0	18.8	37.5	4.7	100.0

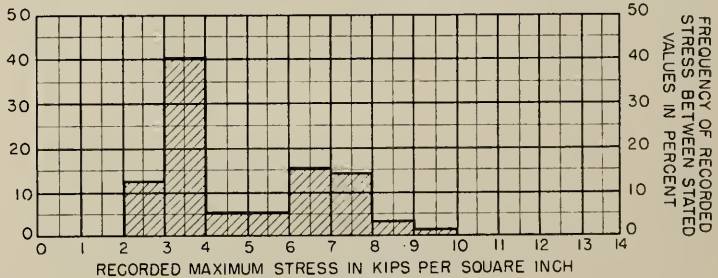
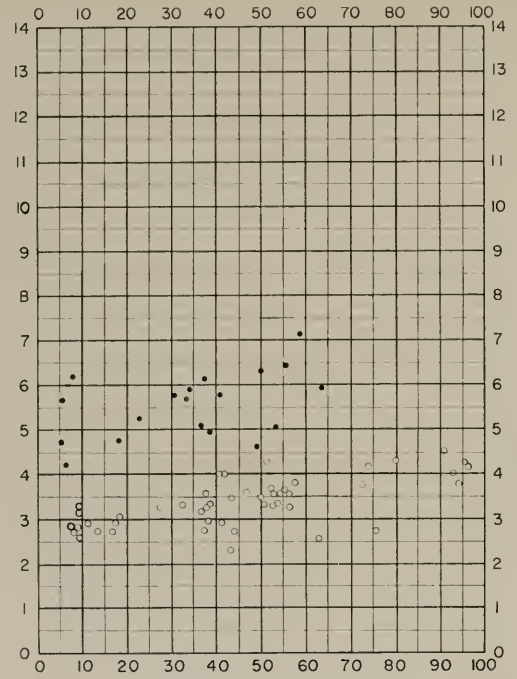

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(SOUTH GIRDER)

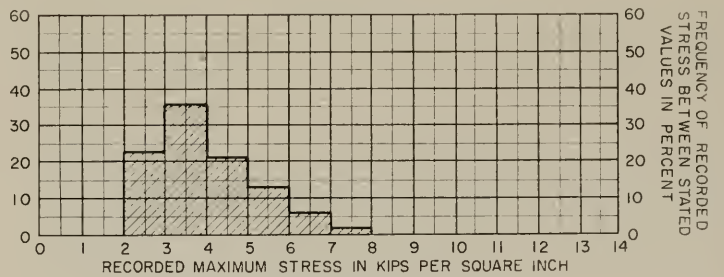
FIG 104
C.M.ST.P.&P.R.R. BRIDGE TESTS
40'-0 DECK PLATE GIRDER-EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
FREQUENCY OF MAXIMUM STRESSES
SOUTH GIRDER



RECORDED MAXIMUM STRESSES
(SOUTH GIRDER)

SYMBOL • STEAM LOCOMOTIVES
o DIESEL LOCOMOTIVES

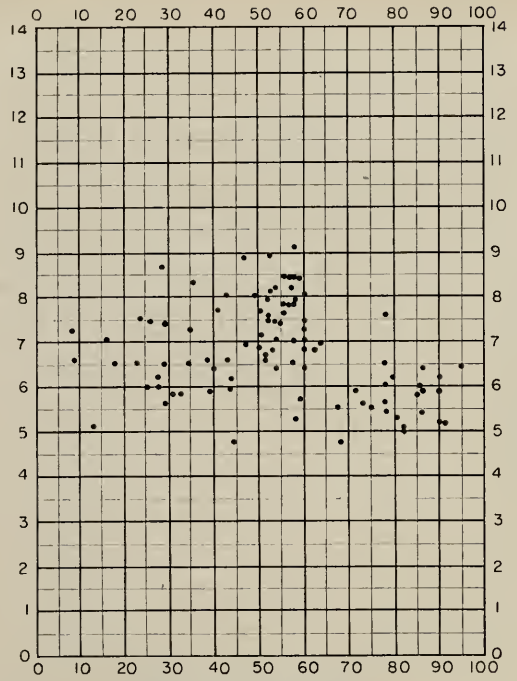
STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S2	S3		2 AXLE	3 AXLE	S2	S3	
7.0 TO 8.0			1		1			1.5		1.5
6.0 " 7.0			2	2	4			3.0	3.0	6.0
5.0 " 6.0			8	1	9			11.7	1.5	13.2
4.0 " 5.0	4	5	5		14	6.0	7.5	7.5		21.0
3.0 " 4.0	20	4			24	29.9	6.0			35.9
2.0 " 3.0	10	5			15	14.9	7.5			22.4
TOTAL READINGS	34	14	16	3	67	50.8	21.0	23.7	4.5	100.0



FREQUENCY OF MAXIMUM STRESSES
(SOUTH GIRDER)

FIG 105
C.M.ST.P & P.RR BRIDGE TESTS
40'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

FREQUENCY OF MAXIMUM STRESSES
SOUTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(SOUTH GIRDER)
SYMBOL • STEAM LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	STEAM					STEAM				
	A	L2b	S2	S3		A	L2b	S2	S3	
9.0 TO 10.0			1		1			1.1		1.1
8.0 " 9.0			14		14			14.7		14.7
7.0 " 8.0		1	14	10	25		1.1	14.7	10.5	26.3
6.0 " 7.0	6	5	3	13	27	6.3	5.3	3.2	13.7	28.5
5.0 " 6.0	20	6			26	21.0	6.3			27.3
4.0 " 5.0	2				2	2.1				2.1
TOTAL READINGS	28	12	32	23	95	29.4	12.7	33.7	24.2	100.0

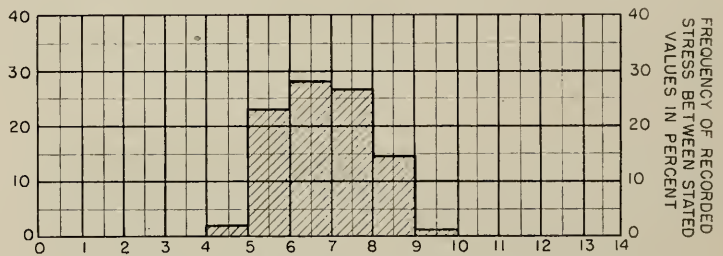
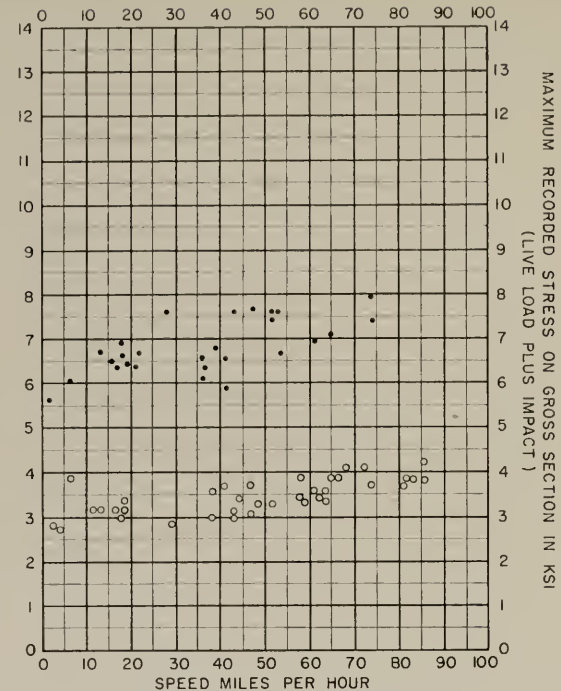

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(SOUTH GIRDER)

FIG 106
C.M ST P&P R R BRIDGE TESTS
46'-8¾ DECK GIRDER SPAN
BALLASTED TIMBER DECK
FLANGE AT CENTER OF GIRDER

FREQUENCY OF MAXIMUM STRESSES
SOUTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)
SYMBOL • STEAM LOCOMOTIVES
o DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S2	S3		2 AXLE	3 AXLE	S2	S3	
7.0 TO 8.0			7	2	9			11.0	3.1	14.1
6.0 " 7.0			15	1	16			23.4	1.6	25.0
5.0 " 6.0			2		2			3.1		3.1
4.0 " 5.0	2	1			3	3.1	1.6			4.7
3.0 " 4.0	20	11			31	31.2	17.2			48.4
2.0 " 3.0	3				3	4.7				4.7
TOTAL READINGS	25	12	24	3	64	39.0	18.8	37.5	4.7	100.0

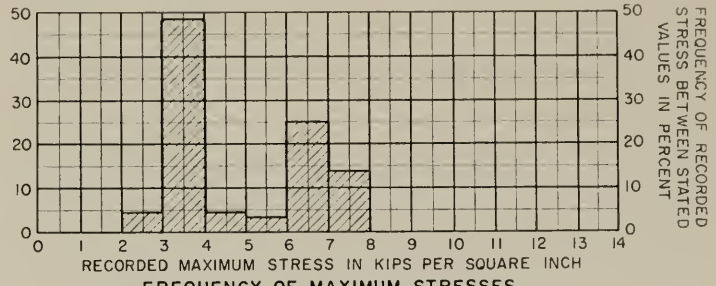
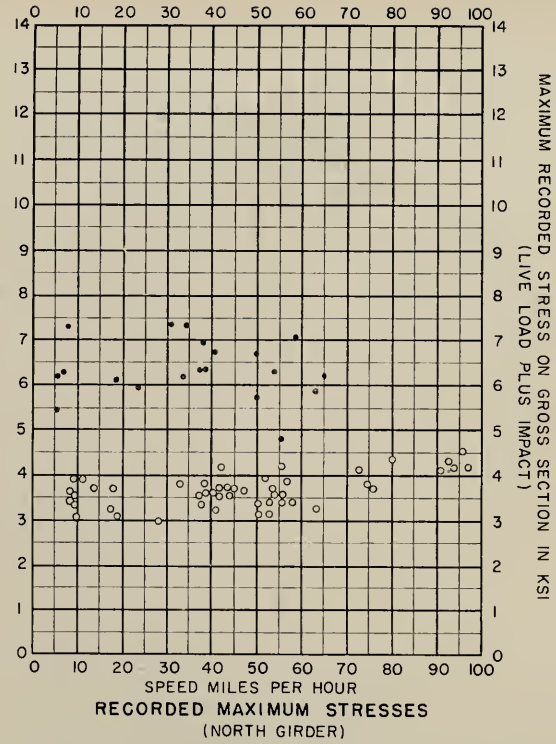

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 107
C.M.ST.P.&P.R.R. BRIDGE TESTS
55'-0 DECK PLATE GIRDER-EASTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
FREQUENCY OF MAXIMUM STRESSES
NORTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)
SYMBOL • STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S2	S3		2 AXLE	3 AXLE	S2	S3	
7 0 TO 8.0			4		4			6 0		6.0
6 0 " 7 0			10		10			14 9		14.9
5 0 " 6 0			2	2	4			3.0	3 0	6 0
4 0 " 5 0	2	7		1	10	3 0	10 4		1.5	14.9
3 0 " 4 0	31	7			38	46 3	10 4			56.7
2 0 " 3 0	1				1	1.5				1 5
TOTAL READINGS	34	14	16	3	67	50.8	20.8	23.9	4.5	100.0

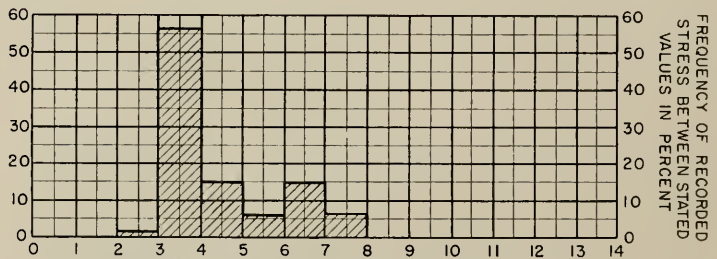
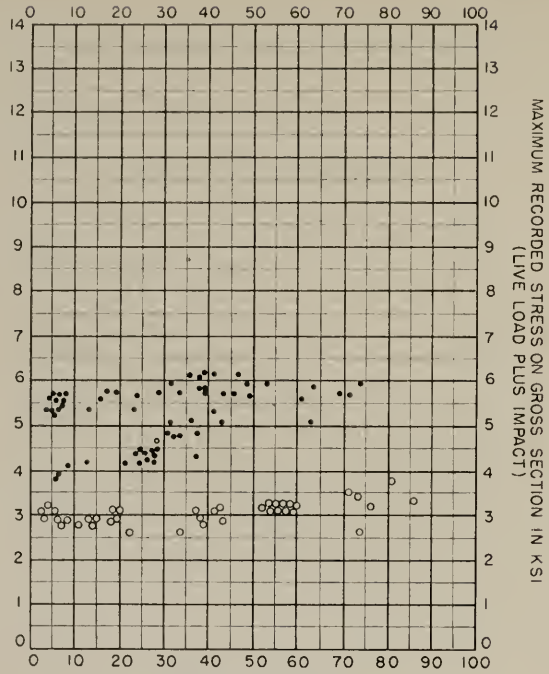

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 108
C.M.ST.P & P.RR. BRIDGE TESTS
55'-0 DECK PLATE GIRDER-WESTBOUND SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
FREQUENCY OF MAXIMUM STRESSES
NORTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)
SYMBOL • STEAM LOCOMOTIVES
o DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	L2b	S3		2 AXLE	3 AXLE	L2b	S3	
6.0 TO 7.0				5	5				4.9	4.9
5.0 " 6.0			4	34	38			3.9	33.4	37.3
4.0 " 5.0			18		18			17.7		17.7
3.0 " 4.0	16	7	2		25	15.7	6.8	1.9		24.4
2.0 " 3.0	5	11			16	4.9	10.8			15.7
TOTAL READINGS	21	18	24	39	102	20.6	17.6	23.5	38.3	100.0

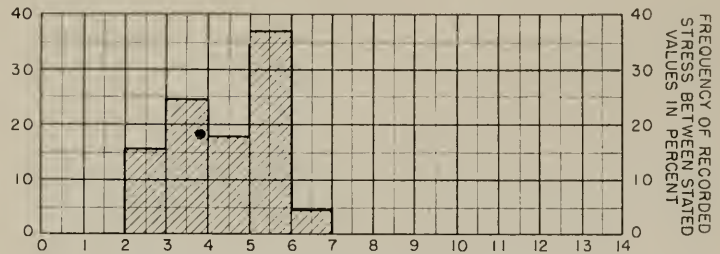
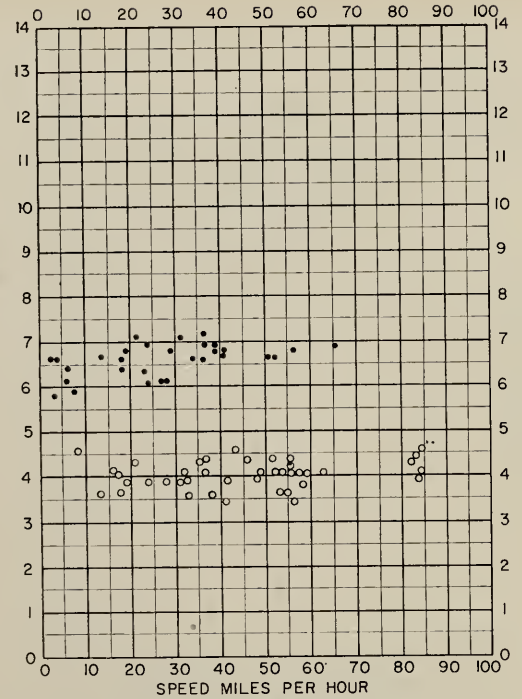

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 109
C.M.ST.P & P.RR. BRIDGE TESTS
85'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
FREQUENCY OF MAXIMUM STRESSES
NORTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)
SYMBOL: • STEAM LOCOMOTIVES
o DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION

STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S2	S3		2 AXLE	3 AXLE	S2	S3	
7.0 TO 8.0			2	1	3			2.8	1.4	4.2
6.0 " 7.0			23	2	25			32.5	2.8	35.3
5.0 " 6.0			2		2			2.8		2.8
4.0 " 5.0	3	21			24	4.2	29.6			33.8
3.0 " 4.0	14	3			17	19.7	4.2			23.9
TOTAL READINGS	17	24	27	3	71	23.9	33.8	38.1	4.2	100.0

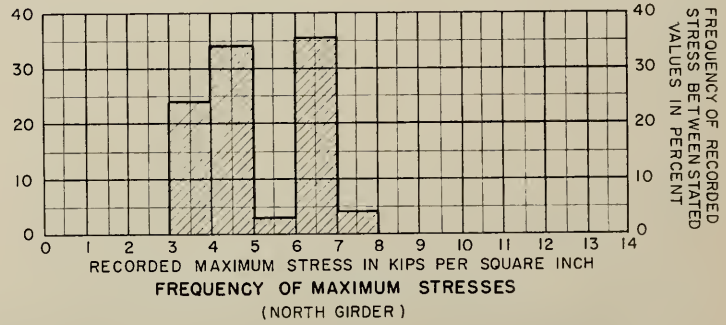
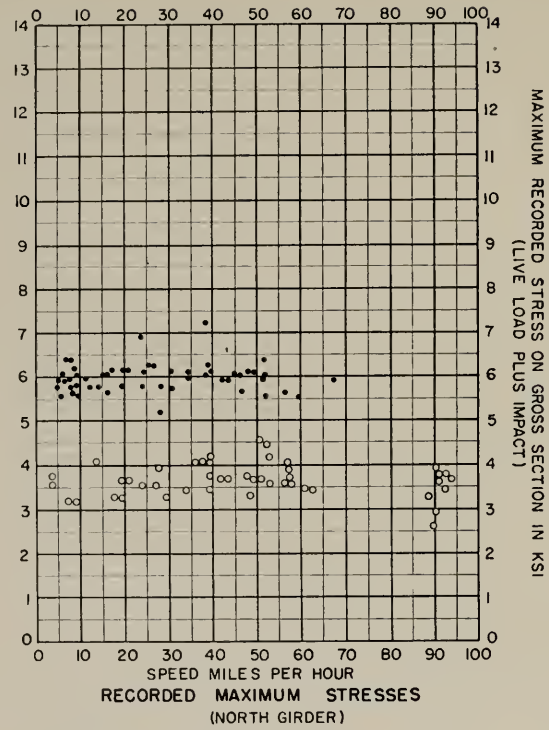

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 110
C.M. ST.P. & P. RR. BRIDGE TESTS
94'-10 DECK GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER
FREQUENCY OF MAXIMUM STRESSES
NORTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)
SYMBOL : • STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS		STEAM			DIESELS		STEAM		
	2 AXLE	3 AXLE	S2	S3		2 AXLE	3 AXLE	S2	S3	
7.0 TO 8.0			1		1			1.0		1.0
6.0 " 7.0			9	16	25			9.1	16.2	25.3
5.0 " 6.0			2	25	27			2.0	25.2	27.2
4.0 " 5.0	9				9	9.1				9.1
3.0 " 4.0	26	9			35	26.3	9.1			35.4
2.0 " 3.0		2			2		2.0			2.0
TOTAL READINGS	35	11	12	41	99	35.4	11.1	12.1	41.4	100.0

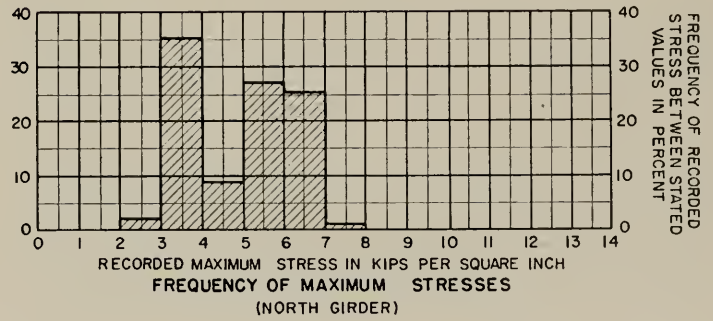
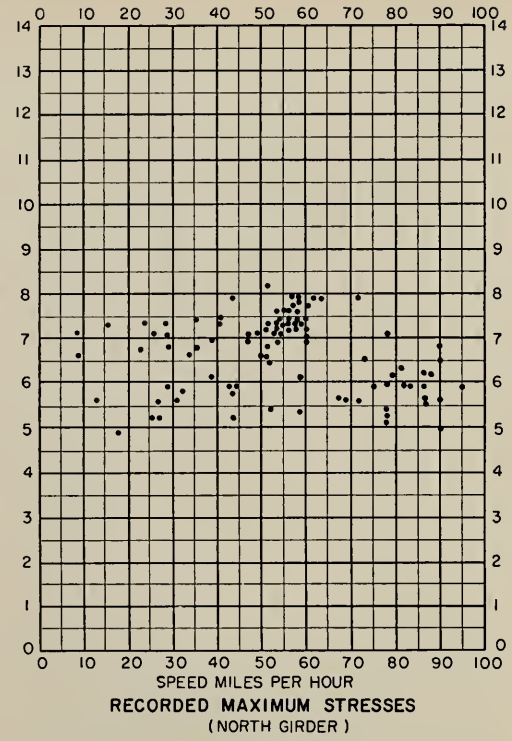

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 111
C.M.ST.P & P RR. BRIDGE TESTS
107'-0 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

FREQUENCY OF MAXIMUM STRESSES

NORTH GIRDER


MAXIMUM RECORDED STRESS ON GROSS SECTION IN KSI
(LIVE LOAD PLUS IMPACT)
SPEED MILES PER HOUR
RECORDED MAXIMUM STRESSES
(NORTH GIRDER)
SYMBOL • STEAM LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	STEAM					STEAM				
	A	L2b	S2	S3		A	L2b	S2	S3	
8.0 TO 9.0			1		1			1.0		1.0
7.0 " 8.0			28	15	43			29.3	15.6	44.9
6.0 " 7.0	8	2	4	8	22	8.3	2.1	4.2	8.3	22.9
5.0 " 6.0	19	9			28	19.8	9.4			29.2
4.0 5.0	1	1			2	1.0	1.0			2.0
TOTAL READINGS	28	12	33	23	96	29.1	12.5	34.5	23.9	100.0

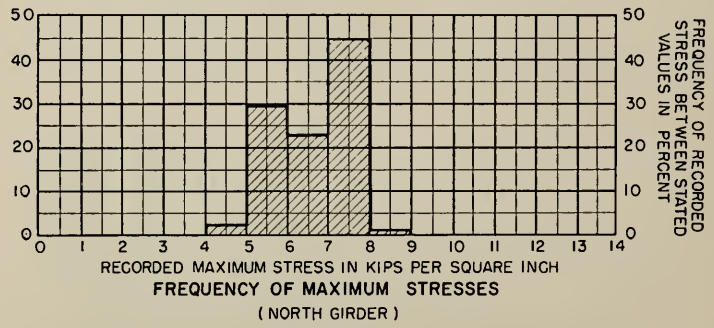
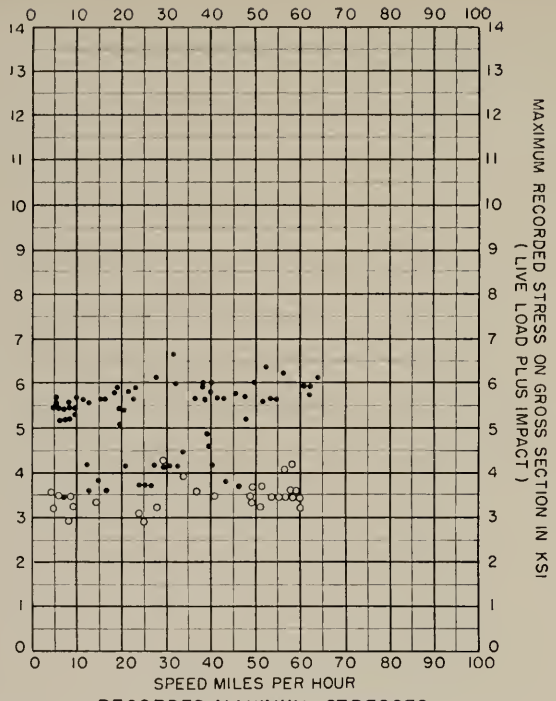

FREQUENCY OF RECORDED STRESS BETWEEN STATED VALUES IN PERCENT
RECORDED MAXIMUM STRESS IN KIPS PER SQUARE INCH
FREQUENCY OF MAXIMUM STRESSES
(NORTH GIRDER)

FIG. 112
C.M. ST P & P R.R BRIDGE TESTS
110'-2 THROUGH GIRDER SPAN
BALLASTED TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

FREQUENCY OF MAXIMUM STRESSES

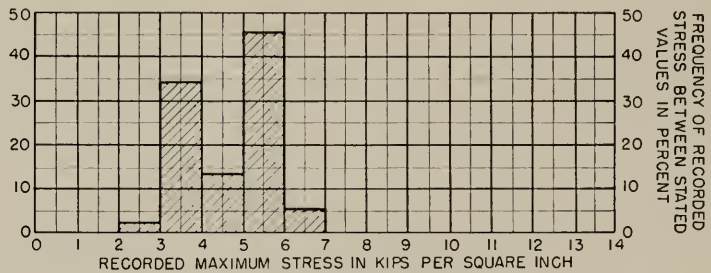
NORTH GIRDER



RECORDED MAXIMUM STRESSES
(SOUTH GIRDER)

SYMBOL • STEAM LOCOMOTIVES
○ DIESEL LOCOMOTIVES

STRESS RANGE DISTRIBUTION										
STRESS RANGE OF RECORDED MAXIMUM STRESS IN KSI	NUMBER OF READINGS FOR EACH STRESS RANGE					PERCENT OF TOTAL READINGS				
	LOCOMOTIVES				TOTAL	LOCOMOTIVES				TOTAL
	DIESELS	STEAM				DIESELS	STEAM			
	2 AXLE	L2b	S2	S3		2 AXLE	L2b	S2	S3	
6.0 TO 7.0			5		5			5.2		5.2
5.0 " 6.0			39	5	44			40.2	5.2	45.4
4.0 " 5.0	3	10			13	3.1	10.3			13.4
3.0 " 4.0	24	9			33	24.7	9.3			34.0
2.0 " 3.0	2				2	2.0				2.0
TOTAL READINGS	29	19	44	5	97	29.8	19.6	45.4	5.2	100.0



FREQUENCY OF MAXIMUM STRESSES
(SOUTH GIRDER)

FIG 113
C.M. ST.P.&P. R.R. BRIDGE TESTS
140'-0" THROUGH GIRDER SPAN
OPEN TIMBER FLOOR
FLANGE AT CENTER OF GIRDER

FREQUENCY OF MAXIMUM STRESSES
SOUTH GIRDER

Advance Report of Committee 3—Ties

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

L. W. Kistler (chairman, subcommittee), J. E. Armstrong, Jr., R. W. Cook, C. M. Long, W. G. Park.

The annual statistics compiled by the Bureau of Railway Economics, AAR, providing information regarding cross-tie renewals and cost data for 1954, are shown in Tables A and B.

Perhaps the outstanding aspect of the statistics for 1954 is the reduction in cross-tie renewals from previous years. The total of 22,902,197 new wood cross ties laid in replacement in 1954 is 6,507,550 less than the renewals in 1953, a reduction of over 22 percent. In terms of ties per mile the reduction was from 90 to 70, and the 5-year average decreased from 90 to 86. This decrease prevailed in all regions, ranging from a reduction of 9 ties per mile in the Central Western to 31 in the Central Eastern.

It is generally conceded that one important factor in this decrease was reduced traffic or earnings, which caused more selective renewals or tie maintenance. Illustrative of the traffic effect on cross tie insertions is the fact that the three regions (Pocahontas, Great Lakes and Central Eastern) having the greatest reduction in equated gross ton miles per mile of maintained track, also had the greatest reduction in cross tie renewals, and in the same order.

During 1954 there were many thousands of second-hand ties reclaimed from discontinued trackage and reinserted but which do not appear under second-hand ties in these statistics because of the methods of accounting followed by many railroads. Since the exact number so used is not known, it is impossible to evaluate their effect on these statistics. It is thought that on some railroads the effect is considerable.

NE

GRI
Ch
Ch
Ch

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1954

Road	Cross ties laid in replacement								Miles of main-tained tracks (Item 25)	Estimated total cross ties in all maintained tracks (Item 24)	Average number of cross ties per mile of main-tained track	Number of equated gross ton-miles in thousands	Number of equated gross ton-miles per mile of main-tained track (thous.)	New wooden cross tie replacement averages			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood(6) & second-hand(e) reapplied ties	Total ties applied						Per cent renewal to all ties in main-tained track	Number laid per mile of main-tained track	Renewal cost per mile of main-tained track	Renewal cost per 1000 equated gross ton-miles
	Number	Aver-age cost	Number	Aver-age cost	Number	Aver-age cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NEW ENGLAND REGION:																	(cents)
Bangor & Aroostook	82 211	$2.19	31 764	$4.48	93 975	$2.96	-	93 975	820.52	2 369 883	2 888	1 807 928	2 203	4.0	115	@339	15.40
Boston & Maine	-	-	148 357	3.89	148 357	3.89	-	148 357	2 606.42	7 703 418	2 956	12 992 126	4 985	1.9	57	222	4.45
Canadian Pacific (Lines in Me.)	-	-	14 650	2.99	14 650	2.99	-	14 650	233.53	740 644	3 172	499 620	2 139	2.0	63	108	6.77
Canadian Pacific (Lines in Vt.)	-	-	14 729	3.42	14 729	3.42	-	15 375	216.54	628 525	2 903	1 658 124	7 657	2.4	71	264	3.45
Central Vermont	-	-	36 663	4.51	36 663	4.51	* 164	14 729	123.78	371 820	3 004	584 296	4 720	4.0	119	407	8.67
Maine Central	42 760	2.38	78 085	3.94	120 845	3.39	-	36 827	489.45	1 455 052	2 973	2 098 863	4 288	2.5	75	338	7.88
New York Connecting	-	-	2 000	4.80	2 000	4.80	-	120 845	1 136.29	3 399 700	2 992	3 580 759	3 151	3.6	106	361	11.45
New York, New Haven & Hartford	-	-	31 099	3.54	31 099	3.54	-	2 000	26.30	82 375	3 132	121 266	4 611	2.4	76	372	3.05
Rutland	-	-	1 574	3.32	1 574	3.32	* 22 298	31 099	3 409.21	10 585 096	3 105	21 126 611	6 197	0.3	9	32	0.52
								23 872	391.51	1 226 000	3 131	670 814	1 713	0.1	4	13	0.78
Total	104 971	2.27	374 296	3.93	479 267	3.56	22 462	501 729	9 453.56	28 562 512	3 021	45 340 407	4 796	1.7	51	181	3.77
GREAT LAKES REGION:																	
Ann Arbor	-	-	41 314	3.86	41 314	3.86	-	41 314	397.66	1 210 587	3 043	1 492 742	3 752	3.4	104	401	10.69
Chamberlain & Indiana	-	-	1 937	3.86	1 937	3.86	* 97	2 034	55.47	180 268	2 889	102 108	1 841	1.2	35	135	7.33
Delaware & Hudson	-	-	74 303	3.74	74 303	3.74	-	74 303	1 277.00	4 184 547	3 280	9 719 625	7 627	1.8	58	218	2.36
Delaware, Lackawanna & Western	-	-	124 469	4.20	124 469	4.20	-	124 469	2 078.51	6 429 478	3 093	14 317 524	6 888	1.9	60	251	3.65
Detroit & Mackinac	8 245	1.70	32 088	3.20	40 333	2.69	-	40 333	269.42	812 398	3 015	227 412	844	5.0	150	433	51.26
Detroit & Toledo Shore Line	-	-	7 724	4.51	7 724	4.51	* 417	8 141	131.42	405 145	3 081	730 192	5 555	1.7	51	230	4.72
Erie	-	-	333 113	3.65	333 113	3.65	-	333 113	4 531.02	13 347 678	2 946	31 674 383	6 991	2.5	74	268	3.84
Grand Trunk Western	-	-	107 520	3.64	107 520	3.64	-	107 520	1 843.07	5 835 462	3 166	10 154 357	5 509	1.8	58	212	3.85
Lehigh & Hudson River	-	-	6 352	4.29	6 352	4.29	* 933	7 285	176.59	567 500	3 697	702 318	6 589	2.2	60	256	3.88
Lehigh & New England	-	-	19 043	4.21	19 043	4.21	-	19 043	216.61	716 583	3 026	627 576	2 650	2.7	80	338	12.76
Lehigh Valley	-	-	151 821	3.92	151 821	3.92	-	151 821	2 358.77	7 112 508	3 015	11 580 619	4 910	2.1	64	252	5.14
Monongahela	-	-	8 522	3.77	8 522	3.77	-	8 522	247.14	725 334	2 932	835 417	3 378	1.2	34	130	3.85
Monteur	-	-	611	3.89	611	3.89	-	611	72.54	208 922	2 880	173 126	2 387	0.3	8	33	1.37
New York Central	-	1 102 408	3.69	1 102 408	3.69	* 14 061	1 116 469	20 320.73	63 008 073	3 101	141 334 621	6 955	1.7	54	200	2.88
New York, Chicago & St.Louis	-	312 497	3.69	312 497	3.69	-	312 497	3 447.14	10 730 000	3 113	29 326 110	8 507	2.9	91	352	4.14
New York, Ontario & Western	-	44 842	3.20	44 842	3.20	-	44 842	651.74	1 872 335	2 873	1 263 093	1 938	2.4	69	220	11.35
New York, Susquehanna & Western	-	7 082	2.81	7 082	2.81	-	7 082	208.63	606 583	2 905	322 413	1 544	1.2	34	95	6.16
Pittsburgh & Lake Erie	-	36 598	3.84	36 598	3.84	-	36 598	783.96	2 396 677	3 057	3 153 720	4 023	1.5	47	179	4.46
Pittsburg & Shawmut	-	5 504	3.72	5 504	3.72	* 16	5 520	175.03	528 908	3 021	1 175 503	3 353	1.7	48	178	13.66
Pittsburgh & West Virginia	-	7 228	4.55	7 228	4.55	-	7 228	179.80	550 522	3 062	957 331	5 324	1.3	40	183	3.44
Wabash	-	215 939	3.95	215 939	3.95	-	215 939	3 156.12	9 698 647	3 136	23 512 050	7 450	2.2	68	270	3.63
Total	8 245	1.70	2 640 853	3.76	2 649 098	3.76	15 524	2 664 622	42 489.33	130 883 138	3 080	282 410 260	6 647	2.0	62	234	3.52
CENTRAL EASTERN REGION:																	
Akron, Canton & Youngstown	15 196	3.46	14 618	3.81	29 814	3.73	* 3 026	32 840	219.75	647 786	2 948	645 452	2 937	4.6	136	507	17.25
Baltimore & Ohio	-	-	450 411	3.00	450 411	3.00	-	450 411	10 325.08	29 395 923	2 847	19 012 429	7 652	1.5	44	131	1.71
Bessemer & Lake Erie	-	-	14 721	4.83	14 721	4.83	-	14 721	451.22	1 443 784	3 200	3 057 439	6 776	1.0	33	144	4.73
Central R.R.of New Jersey	-	-	65 437	3.93	65 437	3.93	-	65 437	1 267.74	3 603 629	2 798	6 839 907	5 312	1.8	51	200	3.76
Chicago & Eastern Illinois	-	-	60 275	3.46	60 275	3.46	-	60 275	1 326.06	4 035 624	3 043	6 320 066	4 917	1.5	45	157	3.20
Chicago & Illinois Midland	-	-	19 017	3.57	19 017	3.57	-	19 017	173.34	516 206	2 978	1 092 661	1 704	3.7	110	393	5.53
Chicago, Indpls.& Louisville	-	-	47 209	3.24	47 209	3.24	-	47 209	722.69	2 243 576	3 104	3 260 449	4 512	2.1	65	212	4.69
Detroit, Toledo & Ironton	936	0.40	57 652	3.51	58 588	3.46	-	58 588	606.61	1 752 797	2 880	2 152 385	3 537	3.3	96	333	9.41
Elgin, Joliet & Eastern	-	-	15 556	2.94	15 556	2.94	-	15 556	850.46	2 611 930	3 071	2 662 105	3 130	0.6	18	54	1.72
Illinois Terminal	-	-	25 960	2.98	25 960	2.98	* 29 543	55 503	523.67	1 645 377	3 141	1 070 811	2 045	1.5	50	148	7.22
Long Island	-	-	60 332	3.73	60 332	3.73	-	60 332	772.85	2 230 914	2 887	3 686 362	4 770	2.7	78	291	6.11
Missouri-Illinois	-	-	7 059	2.67	7 059	2.67	-	7 059	217.51	682 919	3 140	424 626	1 952	1.0	32	87	4.44
Pennsylvania	-	-	883 136	3.74	883 136	3.74	-	883 136	21 270.11	61 024 668	2 869	165 551 919	7 783	1.4	42	155	1.99
Penna.-Reading Seashore Lines	-	-	38 092	3.56	38 092	3.56	-	38 092	557.18	1 514 642	2 718	1 057 302	1 898	2.5	68	243	12.82
Reading Co.	-	-	121 005	3.79	121 005	3.79	-	121 005	2 752.46	7 663 151	2 784	15 195 522	5 521	1.6	44	167	3.02
Staten Island Rapid Transit	-	-	3 852	3.54	3 852	3.54	-	3 852	90.93	232 781	2 560	130 091	1 431	1.7	42	150	10.49
Western Maryland	382	2.56	55 403	4.30	55 785	4.29	-	55 785	1 134.94	3 289 168	2 898	6 948 632	6 122	1.7	49	211	3.44
Total	16 514	3.45	1 939 795	3.54	1 956 309	3.54	32 569	1 988 878	43 284.62	124 574 877	2 878	299 300 460	6 915	1.6	45	160	2.32
POCAHONTAS REGION:																	
Atlantic & Danville	-	-	19 859	2.74	19 859	2.74	-	19 859	228.84	675 000	2 950	264 349	1 155	2.9	87	238	20.62
Chesapeake & Ohio	-	-	441 108	3.40	441 108	3.40	-	441 108	8 086.34	24 508 104	3 031	64 582 046	7 987	1.8	55	185	2.32
Norfolk & Western	-	-	296 627	3.18	296 627	3.18	* 3 017	299 644	4 333.20	13 432 920	3 100	42 665 686	9 846	2.2	68	218	2.71
Richmond, Fred'burg & Potomac	-	-	56 113	3.82	56 113	3.82	* 1 870	57 983	412.77	1 235 000	2 992	2 172 974	12 532	4.5	136	519	4.14
Virginian	-	-	83 728	3.40	83 728	3.40	-	83 728	954.09	2 930 673	3 072	8 001 465	6 386	2.9	88	299	3.56
Total	-	-	897 435	3.34	897 435	3.34	4 887	902 322	14 015.24	42 781 697	3 053	120 686 520	8 611	2.1	64	214	2.48
SOUTHERN REGION:																	
Alabama Great Southern	-	-	46 722	3.44	46 722	3.44	-	46 722	570.20	1 720 546	3 017	4 190 521	7 349	2.7	82	282	3.84
Atlanta & St.Andrews Bay	-	-	5 916	4.48	5 916	4.48	-	5 916	119.27	362 082	3 036	598 651	5 019	1.6	50	222	4.43
Atlanta & West Point	-	-	22 035	3.67	22 035	3.67	-	22 035	147.08	438 487	2 981	719 692	4 893	5.0	150	550	11.28
Atlantic Coast Line	-	-	629 937	3.43	629 937	3.43	-	629 937	7 224.94	22 469 563	3 110	39 682 211	5 493	2.8	89	299	4.45
Central of Georgia	-	-	246 804	3.32	246 804	3.32	-	246 804	2 662.08	6 537 914	2 890	8 852 541	3 913	3.8	109	340	8.69
Charleston & Western Carolina	-	-	93 233	3.84	93 233	3.84	-	93 233	436.71	1 281 665	2 935	1 270 148	2 908	7.3	213	821	28.22
Clin., New Orleans & Tex.Pac.	-	-	60 592	3.77	60 592	3.77	-	60 592	672.89	1 991 691	2 960	9 274 722	13 783	3.0	90	340	2.47
Clinchfield	-	-	105 815	3.07	105 815	3.07	-	105 815	630.61	1 810 642	3 205	4 463 499	10 341	3.7	246	753	7.27
Columbus & Greenville	-	-	20 849	2.97	20 849	2.97	-	20 849	295.60	651 301	3 168	192 672	937	3.2	101	301	32.09
Florida East Coast	5 418	3.38	155 112	3.72	160 530	3.67	-	160 530	1 162.63	3 374 780	2 903	6 727 240	5 786	4.8	138	507	7.76
Georgia	-	-	70 114	3.39	70 114	3.39	-	70 114	442.31	1 343 326	3 037	1 745 652	3 947	5.2	159	538	13.63
Georgia & Florida	67 400	2.19	25 747	3.18	93 147	2.46	-	91 147	386.18	1 042 686	2 700	595 812	1 543	6.9	241	593	36.45
Georgia, Southern & Florida	1 111	1.94	179 890	2.30	181 001	2.30	* 12 710	181 001	559.29	1 759 680	3 146	2 372 764	4 242	10.3	324	743	17.52
Gulf, Mobile & Ohio	-	-	309 120	3.24	309 120	3.24	-	321 830	5 818.67	20 000 988	3 050	40 737 889	6 373	2.8	84	283	4.59
Illinois Central	-	-	827 366	3.37	827 366	3.37	-	827 366	10 403.13	32 075 969	3 082	43 941 671	6 372	3.5	101	315	4.75
Louisville & Nashville	-	-	680 203	3.13	680 203	3.13	-	680 203	6 794.90	19 328 072	2 841	37 558	5 530	3.4	205	629	14.40
Mississippi Central	-	-	35 592	3.08	35 592	3.08	* 161	35 663	173.55	551 543	3 178	137 558	1 131	6.4	114	358	7.15
Nashville, Chatt.& St.Louis	-	-	166 747	3.13	166 747	3.13	-	166 747	1 460.89	3 996 995	2 735	5 006	7 312	1.1	66	260	3.30
New Orleans & Northeastern	-	-	19 260	3.96	19 260	3.96	-	19 260	293.24	867 301	2 958	7 312 731	2 309 688	2.2	65	260	21.01
Norfolk Southern	80 696	1.69	75 887	2.99	156 583	2.32	-	156 583	724.80	2 120 047	2 925	2 578 534	2 178	7.4	216	501	5.21
Seaboard Air Line	-	-	490 189	3.57	490 189	3.57	-	490 189	6 480.43	16 535 428	3 017	33 655 885	5 141	3.0	89	320	4.76
Southern Ry.	762	2.62	624 719	3.53	625 481	3.51	-	625 481	8 361.61	25 939 998	3 102	49 982 674	5 979	2.4	75	264	4.42
Tennessee Central	8 766	1.75	42 147	2.90	50 913	2.70	-	50 913	349.66	1 058 770	3 028	652 108	2 865	4.8	144	394	21.11
Western Ry.of Alabama	1 395	1.24	31 081	3.66	31 276	3.65	-	31 276	186.63	558 093	2 990	869 570	4 659	5.6	168	612	13.13
Total	164 368	1.92	4 964 987	3.33	5 129 355	3.28	12 871	5 142 226	51 743.76	156 403 236	3 023	298 190 308	5 763	3.3	99	325	5.65

NORTH	CENTRAL	SOUTH	CAB
Ch	Al	B	C
Ch	G	I	C
Ch	G	K	C
Du	Ch	K	
Du	Ch	L	
Du	Fl	M	
Gr	M	M	
Gr	S	M	
La	Sh	N	
M	Tr	O	
Ne	Un	S	
S	Un	S	
S	W	S	
		S	
		T	
		T	
		T	

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LANDS CANADIAN RAILROADS

Calendar year ended December 31, 1954

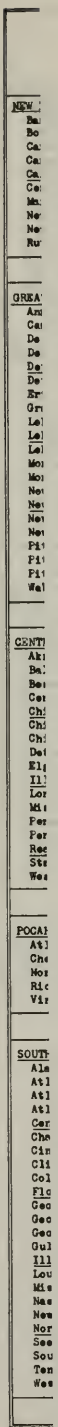
Road	Cross ties laid in replacement: New wooden ties untreated (U) Number	Average cost	New wooden ties treated (T) Number	Average cost	Total all new wooden ties laid Number	Average cost	Ties other than wood (B) & second-hand(s) reapplied ties	Total ties applied	Miles of main-tained tracks (item 25)	Estimated total gross tons in all maintained tracks (item 24)	Average number of gross tons per mile of main-tained track	Number of equated gross tons-miles (thousands)	Number of equated gross ton-miles per mile of main-tained track (thous.)	New wooden cross ties replacement averages: Per cent renewal to all ties in main-tained track	Number laid per mile of main-tained track	Renewal cost per mile of main-tained track	Renewal cost per 1000 equated gross ton-miles
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western	4 164	$1.43	374 953	$3.38	379 117	$3.36	-	379 117	10 879.12	32 249 362	2 964	40 983 252	3 767	1.2	35	$117	3.10
Chicago Great Western	-	-	97 532	3.93	97 532	3.93	-	97 532	1 794.08	5 365 034	2 990	8 087 588	4 508	1.8	54	214	4.74
Chicago,Milwaukee,St.Paul & Pac.	149 576	0.32	574 294	3.30	723 870	2.68	-	723 870	13 360.49	41 087 218	3 075	54 660 791	4 091	1.8	54	145	3.55
Chicago,St.Paul,Minpls.& Omaha	149	1.52	85 370	3.75	85 519	3.74	-	85 519	2 137.65	6 338 365	2 965	6 815 589	3 188	1.3	40	150	4.70
Duluth,Missabe & Iron Range	64	1.71	65 091	3.66	65 155	3.65	-	65 155	1 067.11	3 178 904	2 979	5 243 145	4 912	2.0	61	223	4.54
Duluth,South Shore & Atlantic	257	1.61	77 260	3.31	77 517	3.30	-	77 517	561.22	1 625 339	2 896	1 592 144	2 837	4.8	138	456	16.07
Duluth,Winnipeg & Pacific	1 188	2.03	10 536	3.34	11 724	3.20	-	11 724	205.42	589 195	2 864	1 142 974	5 556	2.0	57	183	3.29
Great Northern	4 694	2.24	65 093	3.59	69 987	3.50	-	69 987	788 436	10 176.08	32 063 708	3 120	56 651 005	5 513	2.4	74	285	5.18
Great Northern	-	-	757 484	3.87	757 484	3.87	* 30 954	788 438	10 176.08	32 063 708	3 120	56 651 005	5 513	2.4	74	285	5.18
Lake Superior & Ishpeming	5 213	1.69	8 923	3.58	14 136	2.88	-	14 136	262.91	788 730	3 000	1 147 536	4 362	1.6	54	155	2.64
Minneapolis & St.Louis	41 163	1.76	169 365	3.35	210 528	3.04	-	210 528	1 531.17	4 588 730	2 997	3 743 492	2 445	4.6	137	417	17.07
Minpls.,St.Paul & S.S.M.(Inc.WC)	401	1.34	447 658	3.33	448 059	3.33	-	448 059	4 806.07	14 440 971	3 007	17 747 026	3 693	3.1	93	310	8.40
Northern Pacific	783	2.26	478 255	3.46	479 038	3.46	-	479 038	9 224.65	26 777 941	2 903	44 182 800	4 790	1.8	52	180	3.35
Spokane International	192	0.25	83 220	3.37	83 412	3.36	-	83 412	176.91	516 697	2 921	442 611	2 502	16.1	471	1 585	63.37
Spokane,Portland & Seattle	-	-	69 909	3.86	69 909	3.86	-	69 909	1 143.05	3 517 287	3 083	6 377 985	5 590	2.0	61	236	4.23
Total	208 082	0.73	3 364 945	3.52	3 572 967	3.36	30 954	3 603 921	57 701.15	173 933 351	3 014	246 497 628	4 307	2.1	62	208	4.83
CENTRAL WESTERN REGION:																	
Atchison,Topeka & Santa Fe	-	-	1 241 775	3.03	1 241 775	3.03	-	1 241 775	19 497.50	62 255 516	3 193	147 469 087	7 563	2.0	64	193	2.55
Chicago,Burlington & Quincy	-	-	485 192	3.29	485 292	3.29	*102 388	587 680	11 743.72	36 264 607	3 088	62 550 670	5 326	1.3	41	136	2.55
Chicago,Rock Island & Pacific	-	-	727 188	3.63	727 188	3.63	-	727 188	9 904.37	29 536 674	2 982	45 407 862	4 686	2.5	73	193	4.12
Colorado & Southern	-	-	42 472	3.32	42 472	3.32	* 3 451	45 923	802.98	2 408 940	3 000	3 771 046	4 699	1.8	53	176	3.74
Colorado & Wyoming	1 855	2.49	13 920	4.96	15 775	4.67	-	15 775	108.01	332 606	3 079	53 390	494	4.7	146	692	137.55
Denver & Rio Grande Western	-	-	169 523	4.21	169 523	4.21	* 27 595	197 118	3 121.37	9 668 100	3 097	17 195 439	5 509	1.8	54	229	4.15
Ft.Worth & Denver	-	-	78 195	3.38	78 195	3.38	* 2 602	80 797	1 221.98	3 658 438	3 010	4 999 455	4 091	2.1	64	216	5.28
Northwestern Pacific	5 335	2.62	83 948	3.49	89 103	3.44	-	89 103	428.60	1 232 350	2 875	2 047 221	4 777	7.2	208	714	14.95
Sacramento Northern	27	3.58	19 000	3.45	19 027	3.45	-	19 027	310.12	932 445	3 007	90 462	292	2.0	61	212	72.65
Southern Pacific Co.-Pac.Lines	6 121	2.12	951 366	3.19	957 687	3.18	* 103	957 790	12 569.24	36 634 651	3 035	124 479 826	10 314	2.6	79	253	2.45
Toledo,Peoria & Western	-	-	27 391	3.32	27 391	3.32	-	27 391	280.82	889 638	3 168	968 957	3 450	3.1	98	324	9.39
Union Pacific	290	2.39	666 330	3.44	666 620	3.44	-	666 620	13 418.61	37 932 486	2 827	138 577 726	10 327	1.8	50	171	1.66
Utah	75	2.80	210	4.24	285	4.07	* 723	1 008	57.13	165 201	2 892	200 782	3 514	0.4	10	42	1.19
Western Pacific	86	3.02	229 321	4.08	229 407	4.08	* 1 509	230 916	1 551.63	4 618 579	2 977	11 291 461	7 277	5.0	148	603	8.29
Total	13 609	2.38	4 736 631	3.20	4 750 240	3.20	136 571	4 888 811	74 516.08	226 550 227	3 040	560 105 362	7 517	2.1	64	204	2.72
SOUTHWESTERN REGION:																	
Beaumont,Sour Lake & Western	-	-	27 021	2.92	27 021	2.92	-	27 021	350.76	448 900	2 978	1 220 689	8 150	6.0	179	524	6.43
Internation-Great Northern	-	-	183 180	2.80	183 180	2.80	-	183 180	1 339.65	4 269 000	3 187	6 887 212	5 141	4.3	137	383	7.46
Kansas City Southern	-	-	60 185	2.99	60 185	2.99	-	60 185	1 319.16	4 173 370	3 164	9 490 329	7 194	1.4	46	136	1.90
Kansas,Oklahoma & Gulf	-	-	37 356	2.97	37 356	2.97	-	37 356	354.25	1 056 719	2 983	1 267 996	3 579	3.6	106	315	6.79
Louisiana & Arkansas	-	-	83 127	3.11	83 127	3.11	-	83 127	885.38	2 800 900	3 256	4 620 243	5 218	2.9	94	295	5.65
Midland Valley	80	1.02	22 764	3.07	22 844	3.07	-	22 844	148.62	1 038 932	2 980	376 554	1 080	2.2	66	201	18.59
Missouri-Kansas-Texas Lines	-	-	386 665	2.94	386 665	2.94	-	386 665	3 919.96	12 418 513	3 168	16 901 204	4 312	3.1	99	290	6.72
Missouri Pacific	630	1.23	942 335	2.86	942 965	2.86	-	942 965	8 752.23	26 992 783	3 084	50 881 482	5 814	3.5	108	308	5.30
New Orleans,Texas & Mexico	-	-	24 268	2.95	24 268	2.95	-	24 268	228.62	699 300	3 059	1 502 256	6 571	3.5	106	313	4.77
Oklahoma City-Ada-Atoka	1 200	1.21	15 468	3.02	16 668	2.89	-	16 668	136.24	392 959	2 884	89 545	657	4.2	122	354	53.84
St.Louis,Brownsville & Mexico	-	-	90 400	2.80	90 400	2.80	-	90 400	776.53	2 342 300	3 016	2 789 659	3 592	3.9	116	327	9.11
St.Louis-San Francisco Lines	133	2.43	486 659	2.89	488 792	2.89	-	488 792	5 793.61	18 234 147	3 147	28 127 360	4 855	2.7	84	243	5.01
St.Louis,San Fran.& Texas	-	-	11 711	2.94	11 711	2.94	-	11 711	157.31	490 743	3 120	745 468	4 739	2.4	74	219	4.62
St.Louis Southwestern Lines	-	-	128 400	3.00	128 400	3.00	* 13 576	141 976	1 740.07	5 397 388	3 102	12 168 463	6 993	2.4	74	221	3.16
San Antonio,Uvalde & Gulf	-	-	51 429	2.64	51 429	2.64	-	51 429	368.45	1 025 800	2 784	684 971	1 859	5.0	140	396	21.32
Texas & New Orleans	-	-	592 472	2.53	592 472	2.53	-	592 472	5 577.43	15 418 669	2 765	32 081 798	5 752	3.8	106	268	4.67
Texas & Northern	-	-	1 205	3.24	1 205	3.24	-	1 205	15.06	54 851	3 642	23 336	1 550	2.2	80	259	16.74
Texas & Pacific	-	-	290 184	2.89	290 184	2.89	-	290 184	2 241.13	6 549 573	2 922	16 342 193	7 284	4.4	129	375	4.58
Texas Mexican	1 238	0.50	27 216	3.64	28 454	3.50	-	28 454	236.30	748 598	3 168	193 510	819	3.8	120	421	51.45
Total	3 281	0.99	3 464 245	2.84	3 467 526	2.84	13 576	3 481 102	34 340.76	103 653 443	3 018	188 408 268	5 486	3.3	101	286	5.22
Grand total - United States	519 010	1.56	22 363 187	3.34	22 902 197	3.30	271 414	23 173 611	327 544.50	987 342 481	3 014	2 042 947 213	6 237	2.3	70	230	3.69
CANADIAN ROADS:																	
Canadian National	260 459	1.57	3 067 697	3.12	3 328 156	3.00	-	3 328 156	28 180.00	82 030 980	2 911	[b]	4.00	4.0	128	354	[b]
Canadian Pacific	59 235	2.36	2 105 440	3.31	2 164 675	3.31	-	2 164 675	21 221.2	61 494 257	2 898	96 555 608	4 548	3.5	102	337	7.43
Ontario & Northland	2 285	2.66	152 323	4.18	154 608	4.16	-	154 608	684.00	1 925 600	2 900	1 684 229	2 484	8.0	233	966	3.81

[a] Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.

[b] Not reported.

Note: "Average cost" as shown in Columns 3, 5 and 7, represents storekeepers average cost of ties charged out and used. They are not the actual costs or the prices paid for the ties purchased during the period.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.,
from Annual Reports of Class I Railways to the Interstate Commerce Commission.
May 1955



NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND PER CENT OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1950 to 1954, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1950	1951	1952	1953	1954	5 year average	1950	1951	1952	1953	1954	5 year average	1950	1951	1952	1953	1954	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	167	141	149	111	115	137	$304	$305	$437	$304	$339	$338	5.8	4.9	5.2	3.8	4.0	4.7
Boston & Maine	64	52	69	64	57	61	213	180	280	228	222	225	2.2	1.8	2.3	2.2	1.9	2.1
Canadian Nat. Lines in New England	75	53	33	56	63	60	168	123	150	158	188	157	2.4	1.7	1.7	1.8	2.0	1.9
Canadian Pacific (lines in Me.)	91	86	103	90	71	88	206	208	295	319	264	258	3.1	3.0	3.6	3.2	2.4	3.0
Canadian Pacific (lines in Vt.)	104	119	143	117	119	120	211	289	371	364	407	328	3.5	4.0	4.8	3.9	4.0	4.0
Central Vermont	49	38	57	63	75	60	134	165	220	263	338	224	1.7	2.0	1.9	2.1	2.5	2.0
Maine Central	105	64	118	85	106	96	276	230	477	302	361	329	3.5	2.1	3.9	2.8	3.6	3.2
New York, New Haven & Hartford	91	28	52	33	76	56	377	116	251	163	372	256	2.9	0.9	1.7	1.1	2.4	1.8
Rutland	60	28	44	47	9	38	189	68	164	182	32	131	1.9	0.9	1.4	1.5	0.3	1.2
	32	21	1	1	4	12	105	65	3	2	13	38	1.0	0.7	0.03	0.02	0.1	0.4
Total	76	52	70	63	51	62	210	158	257	221	181	205	2.5	1.7	2.3	2.1	1.7	2.1
GREAT LAKES REGION:																		
Ann Arbor	117	123	103	126	104	115	363	388	371	480	401	401	3.9	4.1	3.4	4.1	3.4	3.8
Cambria & Indiana	21	12	20	32	35	24	66	43	85	129	135	92	0.7	0.4	0.7	1.1	1.2	0.8
Delaware & Hudson	107	106	98	110	38	96	354	390	339	394	218	331	3.4	3.3	3.1	3.5	1.8	3.0
Delaware, Lackawanna & Western	79	69	71	61	60	68	268	247	279	254	283	260	2.6	2.2	2.3	2.0	1.9	2.2
Detroit & Mackinac	133	231	176	171	150	168	243	703	520	517	433	483	1.7	7.6	5.8	5.7	5.0	5.6
Detroit & Toledo Shore Line	119	67	63	93	51	79	400	303	287	426	230	329	3.9	2.2	2.1	3.1	1.7	2.6
Erie	74	80	97	98	74	85	242	283	340	378	266	302	2.5	2.7	3.3	3.3	2.5	2.9
Grand Trunk Western	105	107	95	64	58	86	291	314	352	243	212	282	3.3	3.4	3.0	2.0	1.8	2.7
Lehigh & Hudson River	55	59	69	69	60	62	184	200	316	312	256	254	2.0	2.2	2.6	2.6	2.2	2.3
Lehigh & New England	120	110	88	89	80	97	438	432	356	370	338	387	4.0	3.6	2.9	2.9	2.7	3.2
Lehigh Valley	75	76	70	70	64	71	253	244	264	273	252	257	2.5	2.5	2.3	2.3	2.1	2.3
Monongahela	40	65	61	44	34	49	128	220	214	164	130	171	1.4	2.2	2.1	1.5	1.2	1.7
Montour	86	94	76	112	8	75	331	462	357	522	33	341	3.0	3.2	2.6	3.9	0.3	2.6
New York Central	69	63	85	96	54	73	225	236	328	363	200	270	2.2	2.1	2.8	3.1	1.7	2.4
New York, Chgo. & St. Louis	101	87	89	108	91	95	305	265	316	411	352	330	3.2	2.8	2.9	3.5	2.9	3.1
New York, Ontario & Western	53	49	19	40	69	46	75	71	75	134	220	119	1.8	1.7	0.6	1.4	2.4	1.6
New York, Susquehanna & Western	28	43	49	39	34	39	81	187	231	178	95	154	1.0	1.5	1.7	1.4	1.2	1.4
Pittsburgh & Lake Erie	95	77	57	92	47	74	321	254	209	361	179	265	3.1	2.5	1.9	3.0	1.5	2.4
Pittsburg & Shawmut	52	97	96	62	48	71	173	405	390	243	178	278	1.8	3.4	3.4	2.2	1.7	2.5
Pittsburgh & West Virginia	103	113	104	91	40	90	381	438	452	408	183	372	3.4	3.7	3.4	3.0	1.3	3.0
Wabash	92	86	76	85	68	81	296	285	293	334	270	296	3.0	2.7	2.4	2.7	2.2	2.6
Total	78	75	84	91	62	78	251	259	326	349	234	282	2.6	2.4	2.7	3.0	2.0	2.5
CENTRAL EASTERN REGION:																		
Akron, Canton & Youngstown	56	133	123	101	136	106	165	362	427	357	507	364	1.9	3.8	4.1	3.4	4.6	3.6
Baltimore & Ohio	104	68	56	36	44	66	290	252	168	111	131	190	3.7	3.1	2.0	1.3	1.5	2.3
Bessemer & Lake Erie	54	61	58	58	33	53	221	253	279	270	144	233	1.7	2.0	1.9	1.9	1.0	1.7
Central R.R. of N.J. (incl. CRRofPa.)	54	70	58	65	51	60	198	236	223	247	200	221	1.8	2.5	2.1	1.8	1.8	2.0
Chicago & Eastern Illinois	38	50	63	66	45	52	137	179	240	244	157	191	1.2	1.7	2.1	2.2	1.5	1.7
Chicago & Illinois Midland	80	118	51	47	110	81	293	416	201	180	393	297	2.6	3.9	1.7	1.6	3.7	2.7
Chicago, Indianapolis & Louisville	175	218	133	165	65	151	470	632	405	521	212	448	5.6	7.0	4.3	5.3	2.1	4.9
Detroit, Toledo & Ironton	90	114	96	139	96	107	241	328	300	424	333	325	3.1	4.0	3.3	4.7	3.3	3.7
Elgin, Joliet & Eastern	51	65	31	29	18	39	149	189	106	99	54	119	1.7	2.1	1.0	1.0	0.6	1.3
Illinois Terminal	90	72	84	78	50	75	223	187	235	226	148	204	2.9	2.3	2.7	2.4	1.5	2.4
Long Island	115	103	82	84	78	92	348	358	355	338	291	338	4.0	3.8	2.9	2.9	2.7	3.2
Missouri-Illinois	194	128	194	41	32	118	438	327	411	113	87	235	6.2	4.1	5.2	1.3	1.0	3.8
Pennsylvania	89	80	94	94	42	80	278	269	351	357	155	282	3.1	2.8	3.3	3.3	1.4	2.8
Penna.-Reading Seashore Lines	64	61	101	89	68	77	248	235	442	402	243	314	2.3	2.2	3.7	3.3	2.5	2.8
Reading Co.	88	88	43	71	44	68	290	274	162	290	167	237	3.2	3.2	1.5	2.8	1.6	2.5
Staten Island Rapid Transit	59	45	45	71	42	52	208	167	146	215	150	177	2.3	1.7	1.7	2.8	1.7	2.0
Western Maryland	72	75	76	76	49	70	233	261	277	302	211	257	2.5	2.6	2.5	2.5	1.7	2.4
Total	91	83	78	76	45	75	275	265	281	280	160	252	3.2	2.9	2.7	2.6	1.6	2.6
POCAHONTAS REGION:																		
Atlantic & Danville	118	115	140	89	87	110	276	278	390	249	238	286	4.0	3.9	4.0	3.1	2.9	3.6
Chesapeake & Ohio	81	80	80	79	55	75	217	250	274	276	185	240	2.7	2.6	2.6	2.6	1.8	2.5
Norfolk & Western	137	130	124	115	68	115	373	383	421	370	218	351	4.4	4.2	4.0	3.7	2.2	3.7
Richmond, Fred'burg & Potomac	47	81	89	97	136	90	138	270	313	361	519	320	1.6	2.8	3.0	3.2	4.5	3.0
Virginian	114	142	117	114	88	115	301	397	365	374	299	347	3.7	4.6	3.8	3.7	2.9	3.7
Total	101	100	97	93	64	91	270	302	326	314	234	285	3.3	3.3	3.2	3.1	2.1	3.0
SOUTHERN:																		
Alabama Great Southern	147	100	93	80	82	100	470	338	354	292	282	347	4.8	3.3	3.1	2.6	2.7	3.3
Atlanta & St. Andrews Bay	172	161	146	110	50	128	584	624	631	487	222	510	5.7	5.4	4.8	3.6	1.6	4.2
Atlanta & West Point	160	158	172	169	150	162	489	535	557	613	550	545	5.3	5.3	5.8	5.7	5.0	5.4
Atlantic Coast Line	99	107	151	153	87	119	261	354	541	537	299	394	3.2	3.5	4.9	4.9	2.8	3.9
Central of Georgia	132	153	130	100	109	125	293	343	373	306	340	331	4.6	5.3	4.5	3.5	3.8	4.3
Charleston & Western Carolina	208	235	216	191	213	213	553	817	795	762	821	750	7.2	7.9	7.5	6.5	7.3	7.3
Cincinnati, New Orleans & Tex. Pac.	161	137	107	97	90	118	513	485	389	363	340	414	5.4	4.6	3.6	3.3	3.0	4.0
Clinchfield	286	310	366	457	246	333	806	998	1160	1487	753	1037	9.4	9.9	11.4	14.3	7.7	10.5
Columbus & Greenville	143	139	88	98	101	114	311	319	221	249	301	280	4.5	4.4	2.9	3.1	3.2	3.6
Florida East Coast	133	117	150	134	138	134	391	403	541	490	507	466	4.6	4.0	5.2	4.6	4.8	4.6
Georgia R.R.	145	160	163	162	159	158	390	482	522	541	538	495	4.8	5.3	5.4	5.3	5.2	5.2
Georgia & Florida	248	314	283	250	242	263	340	456	582	623	593	519	9.2	11.8	9.7	9.3	8.9	9.7
Georgia, Southern & Florida	211	224	190	169	324	222	487	534	613	588	743	593	6.7	6.8	6.0	5.4	10.3	7.0
Gulf, Mobile & Ohio	122	106	138	131	88	117	328	293	409	406	286	342	3.9	3.4	4.4	4.1	2.8	3.7
Illinois Central	144	145	128	101	84	120	389	374	378	319	283	349	4.7	4.8	4.2	3.3	2.8	4.0
Louisville & Nashville	100	118	131	128	101	116	259	319	377	392	315	332	3.5	4.1	4.6	4.5	3.5	4.0
Mississippi Central	103	135	174	215	205	166	245	343	493	668	629	476	3.2	4.2	5.5	6.8	6.4	5.2
Nashville, Chattanooga & St. Louis	136	159	162	150	114	144	333	421	477	492	358	416	5.0	5.8	5.9	5.5	4.2	5.3
New Orleans & Northeastern	141	92	76	67	66	88	470	309	287	262	260	318	4.8	3.1	2.6	2.3	2.2	3.0
Norfolk Southern	210	166	236	249	216	215	444	387	551	592	501	495	7.2	5.7	8.2	8.5	7.4	7.4
Seaboard Air Line	148	127	104	72	89	108	378	387	339	249	320	335	4.9	4.2	3.5	2.4	3.0	3.6
Southern Ry. System	111	102	86	82	75	91	338	328	302	293	264	305	3.6	3.3	2.8	2.7	2.4	3.0
Tennessee Central	136	132	115	110	146	128	315	319	347	338	394	343	4.5	4.4	3.8	3.6	4.8	4.2
Western Ry. of Alabama	162	185	199	168	168	176	495	611	645	609	612	594	5.4	6.2	6.6	5.6	5.6	5.9
Total	129	129	130	118	99	121	343	367	411	386	325	366	4.3	4.3	4.3	3.9	3.3	4.0

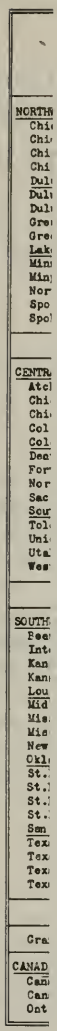


Table 8

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1950 to 1954, inclusive

Note: All figures are exclusive of bridge and switch ties

Head	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1950	1951	1952	1953	1954	5 year average	1950	1951	1952	1953	1954	5 year average	1950	1951	1952	1953	1954	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	90	88	68	77	35	72	$229	$228	$206	$265	$117	$209	3.0	3.0	2.3	2.6	1.2	2.4
Chicago Great Western	217	66	100	75	54	103	744	238	382	297	214	375	7.3	2.3	3.1	2.5	1.8	3.4
Chicago,Milwaukee,St.Paul & Pacific	23	35	50	64	54	45	55	77	148	175	145	120	0.7	1.1	1.6	2.1	1.8	1.5
Chicago,St.Paul,Minpls.& Omaha	89	84	57	76	40	69	253	251	183	278	150	223	3.0	2.8	1.9	2.6	1.3	2.3
Duluth,Missabe & Iron Range	60	46	55	67	61	58	170	133	170	218	223	183	2.0	1.7	2.0	2.2	2.0	2.0
Duluth,South Shore & Atlantic	156	122	116	185	138	143	384	321	335	593	456	418	5.2	4.1	3.9	6.4	4.6	4.9
Duluth,Winnipeg & Pacific	173	125	98	75	57	106	420	312	246	211	183	274	5.9	4.2	3.3	2.6	2.0	3.6
Great Northern	96	108	91	89	74	92	282	328	310	331	285	307	3.1	3.5	2.9	2.8	2.4	2.9
Green Bay & Western	109	108	109	192	253	154	316	386	402	679	883	533	3.8	3.8	3.8	6.7	8.8	5.4
Lake Superior & Ishpeming	112	107	86	77	54	87	220	226	197	209	155	201	3.7	3.6	2.9	2.5	1.8	2.9
Minneapolis & St.Louis	190	153	178	165	137	165	468	390	498	488	417	452	6.3	5.1	5.9	5.5	4.6	5.5
Minpls.,St.Paul & S.S.Marie (incl.Wis.C.)	98	97	98	101	93	97	236	245	336	346	310	295	3.3	3.3	3.7	3.4	3.1	3.3
Northern Pacific	49	52	53	54	52	52	131	140	154	180	180	157	1.7	1.8	1.8	1.9	1.8	1.8
Spokane International	313	378	393	432	471	397	438	804	1256	1443	1585	1105	10.7	13.0	13.5	14.8	16.1	13.6
Spokane,Portland & Seattle	67	63	42	55	61	58	173	142	161	211	236	185	2.2	2.0	1.3	1.7	2.0	1.8
Total	77	75	73	79	62	73	207	203	229	263	208	222	2.6	2.5	2.4	2.6	2.1	2.4
CENTRAL WESTERN REGION:																		
Atchison,Topeka & Santa Fe	60	61	64	68	64	63	167	177	186	211	193	187	1.9	1.9	2.0	2.1	2.0	2.0
Chicago,Burlington & Quincy	63	58	48	58	43	54	170	161	141	195	136	161	2.1	1.9	1.5	1.9	1.3	1.7
Chicago,Rock Island & Pacific	88	82	85	81	73	82	202	206	226	218	193	209	3.0	2.8	2.8	2.7	2.5	2.8
Colorado & Southern	59	55	53	67	53	57	170	165	175	224	176	182	2.0	1.8	1.8	2.2	1.8	1.9
Colorado & Wyoming	18	152	82	29	146	90	78	773	389	109	682	406	1.3	5.2	2.7	0.9	4.7	3.0
Denver & Rio Grande Western	60	60	61	79	54	63	159	211	216	327	229	240	1.9	1.9	2.0	2.5	1.8	2.0
Northwestern Pacific	64	63	88	71	64	70	184	197	261	225	216	217	2.1	2.1	2.9	2.4	2.1	2.3
Sacramento Northern	175	196	215	245	208	208	431	602	702	802	714	650	6.0	6.8	7.4	8.5	7.2	7.2
Southern Pacific Co.- Pac.Lines	68	62	49	57	61	59	184	180	165	196	212	187	2.3	2.1	1.6	1.9	2.0	2.0
Toledo,Peoria & Western	77	72	78	78	74	75	192	231	269	248	253	239	2.4	2.4	2.6	2.5	2.6	2.5
Union Pacific	92	64	78	88	98	84	202	209	267	306	324	262	2.9	2.0	2.5	2.8	3.1	2.7
Utah Ry.	70	40	77	73	50	62	181	120	264	252	171	98	2.5	1.4	2.7	2.6	1.8	2.2
Western Pacific	52	19	13	23	10	27	184	69	136	89	42	104	1.9	0.7	1.2	0.8	0.4	1.0
Total	144	123	142	142	148	140	388	373	562	567	603	499	4.9	4.1	4.8	4.8	5.0	4.7
SOUTHEASTERN REGION:	70	64	71	73	64	68	187	186	226	239	204	208	2.3	2.1	2.4	2.4	2.1	2.3
Beaumont,Sour Lake & Western	150	137	146	174	179	157	399	407	418	512	524	452	5.0	4.6	4.9	5.8	6.0	5.3
International-Great Northern	178	201	203	176	137	179	441	571	561	513	383	494	5.6	6.4	6.4	5.6	4.3	5.7
Kansas City Southern	76	154	192	182	46	130	192	434	561	582	136	381	2.4	4.9	6.1	5.8	1.4	4.1
Kansas,Oklahoma & Gulf	94	105	150	134	106	118	245	357	450	400	315	353	3.2	3.5	5.0	4.5	3.6	4.0
Louisiana & Arkansas	120	130	210	137	94	138	290	367	589	422	295	393	3.7	4.0	6.4	4.2	2.9	4.2
Midland Valley	85	78	89	82	66	80	212	245	248	237	201	229	2.9	2.6	3.0	2.8	2.2	2.7
Missouri-Kansas-Texas Lines	96	76	116	128	99	103	257	217	331	357	290	290	3.1	2.4	3.7	4.0	3.1	3.1
Missouri Pac fic	140	142	140	122	108	130	350	396	415	368	308	367	4.5	4.6	4.5	3.9	3.5	4.2
Nrw Orleans,Texas & Mexico	188	221	228	185	106	186	495	658	655	545	313	533	6.1	7.2	7.4	6.0	3.5	6.0
Oklahoma City-Ada-Atoka	189	130	169	134	122	147	490	439	419	388	354	418	6.6	4.5	5.9	4.7	4.2	5.2
St.Louis,Brownsville & Mexico	113	118	124	138	116	122	272	331	390	392	327	342	3.7	3.9	4.1	4.6	3.9	4.0
St.Louis-San Francisco	127	91	114	81	84	99	316	243	328	232	243	272	4.0	2.9	3.6	2.6	2.7	3.2
St.Louis,San Francisco & Texas	111	83	105	98	74	94	280	233	282	278	219	258	3.5	2.7	3.4	3.1	2.4	3.0
St.Louis Southwestern Lines	134	140	110	149	74	121	339	374	320	437	221	338	4.3	4.5	3.5	4.8	2.4	3.9
San Antonio,Uvalde & Gulf	132	121	161	150	140	137	276	340	438	425	396	375	3.9	4.2	5.6	5.3	5.0	4.8
Texas & New Orleans	110	95	124	106	106	108	269	234	317	276	268	273	4.0	3.4	4.5	3.8	3.8	3.9
Texas & Northern	64	192	204	136	80	135	113	507	569	390	259	368	1.6	5.0	5.5	3.6	2.2	3.6
Texas & Pacific	139	145	140	139	129	138	326	401	368	396	375	373	4.8	5.0	4.8	4.8	4.4	4.8
Texas Mexican	100	184	133	99	120	127	291	627	453	323	421	423	3.2	5.8	4.2	3.1	3.8	4.0
Total	124	119	135	121	101	120	310	329	383	351	286	332	4.1	3.9	4.4	4.0	3.3	3.9
Grand total, United States	92	87	91	90	70	86	252	257	296	300	230	267	3.0	2.9	3.0	3.0	2.3	2.8
CANADIAN ROADS:																		
Canadian National	145	131	135	139	118	134	306	302	357	406	354	345	5.0	4.5	4.6	4.8	4.0	4.6
Canadian Pacific	134	131	131	128	102	125	312	301	343	407	337	340	4.7	4.6	4.5	4.4	3.5	4.3
Ontario Northland	277	297	283	321	233	282	659	662	874	1073	966	847	9.5	10.2	9.7	11.1	8.0	9.7

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from annual reports of Class I railways to the Interstate Commerce Commission.
May, 1955

Advance Report of Committee 15—Iron and Steel Structures

A. R. Harris, *Chairman*

An Investigation of Fatigue Failures in Structural Members of Ore Bridges Under Service Loadings

A Study of Actual Performance with Recommendations for Improving the Fatigue Life of Structural Members

A Report on a Cooperative Project Between the Purdue University Engineering Experiment Station and the United States Steel Corporation

By L. T. Wyly[1] and M. B. Scott[2]

Assisted by A. L. Flassig, Jr.,[3] J. F. Ely,[4] H. L. Leve,[5] Z. L. Moh,[6] and H. C. Prince[7]

FOREWORD

The AREA Committee on Iron and Steel Structures has been interested for many years in the behavior of structural members subjected to repeated loading, and in 1946 recommended that the Association of American Railroads sponsor a project at Purdue University to determine the cause or causes of failures in floorbeam hangers of truss spans. The study of floorbeam hangers then initiated will be completed upon the publication of the remaining reports of field tests in the near future.

The investigation of fatigue failures in the structural members of ore bridges, as reported herein, is so closely related to the study of floorbeam hangers that the Committee on Iron and Steel Structures feels it desirable to take into consideration the causes of failures in ore bridges when making its recommendations for Manual changes for the design and maintenance of members subjected to a large number of cycles of stress varying from near zero to a maximum. The committee has, therefore, recommended the publication of this report in order to have a complete record on the subject.

DIGEST

The fatigue strength of structural members subjected to cyclic variation of stress is a matter of utmost importance to structural engineers. It has been the subject of a great deal of research, speculation, and study. Laboratory tests have been made by many experimentors in an attempt to discover the mechanism of these fatigue failures. Members of the structural engineering department of Purdue's School of Civil Engineering have made a series of field and laboratory tests aimed at studying the effects of single variables upon this phenomenon and have arrived at a working hypothesis which appears to account for the causes of such failures and to point the way to remedies. The results of these tests have been reported previously in technical literature. (See references 1 to 9 incl., listed at the end of this report.)

[1] Research professor of structural engineering and head of department, Purdue University.

[2] Associate professor of stuctural engineering, Purdue University.

[3] Electronics technician, Association of American Railroads, Research Center, Chicago.

[4] Second Lieutenant, U. S. Army Corps of Engineers, Fort Belvoir, Va. Formerly student at Purdue University.

[5] Graduate student, Purdue University, formerly technical trainee, Bethlehem Steel Corporation. Bethlehem, Pa.

[6] Bridge designer, Indiana State Highway Commission, Bureau of Bridges. Formerly graduate research associate, Purdue University.

[7] Senior designer, American Bridge Division, U. S. Steel Corporation, Chicago.

This paper reports on a series of field tests made on ore handling bridges. These structures constitute, in effect, gigantic fatigue testing machines. The full-size specimens are tested repeatedly under actual service conditions. The load, closely known in magnitude, is nearly constant hour after hour, year after year. The number of cycles of loading is also known to a reasonable degree of accuracy.

This report also includes a study of actual failure records of members of this type of bridge. This study has also brought to light considerable new information which has significance for the fatigue problem. As far as the authors know this investigation provides the first factual information on the actual stress histories of a number of members in important structures which have failed in fatigue in service. The data obtained are used to test the working hypothesis previously developed. The results of the study dovetail well with the results already obtained in the laboratory and form an important and necessary link between controlled experiments and actual service conditions. The results thus tend to support the hypothesis.

A critical summary is made of the significant facts developed in this investigation as viewed in light of the generally accepted mechanism of fatigue failures.

For the design of new bridges, specific recommendations are made covering the members to be included in the critical fatigue category, the proportioning of connections, elimination of certain undesirable structural shapes, changes in end and edge distances, changes in shop and erection practices, (in each case these are changes in customs hallowed by long use), and the methods of installation of new types of connectors. For the protection of existing bridges, recommendations are made regarding the estimate of strength of the present members and connections and regarding the probable success which specific remedial measures are likely to achieve. Finally, recommendations are made regarding essential research on specific critical problems, as yet unsolved.

The data presented in this report are necessarily abbreviated. If, however, further information is desired, the complete records are on file with the United States Steel Corporation and the authors.

INTRODUCTION

On March 22, 1952, the American Bridge Division of the United States Steel Corporation, through its chief engineer, Mr. C. E. Webb, offered to support a research project to investigate the causes of and remedies for fatigue failure in the ore bridges of the corporation, the work to be carried out by the structural department of the School of Civil Engineering of Purdue University under the direction of L. T. Wyly, with the full cooperation and assistance of the corporation. On June 23 of that year, an agreement was signed by the officials of the corporation and the university formally authorizing and setting up this investigation. The contract stated the purpose of the investigation to be:

"a. The prevention of failure of the truss members and details in the truss panels of the American Bridge Division type ore bridge, and
b. The prevention of failure of the Hoover–Mason type ore bridge."

The contract further stated:

"8. This is a cooperative investigation, and the engineers and metallurgists of the Company will work with the University and will assist in solving the problem as follows:
a. By furnishing the University details and experience with the American Bridge Division type and with the Hoover–Mason type ore bridge, including pho-

tographs and descriptions of fractures, reports of physical or chemical tests already made or to be made.

b. By furnishing the University with primary stress analysis of the ore bridge to be tested under the loads to be used in the tests.

c. By sitting in conference with the University forces in studying past experiences, in planning the investigation, and in drawing conclusions from the results of the investigation, and finally in reviewing the proposed remedies."

The project provided an excellent opportunity to secure much needed basic information on the relations of stress history to structural fatigue failure. In the case of most structures, notably railway or highway bridges, it is difficult, if not impossible, to establish with any degree of certainty either the magnitude of the loadings or the number of cycles of a given loading to which the members have been subjected. For a given ore bridge, however, the loading is generally about the same day after day throughout the life of the structure. Also, it is possible to establish from records of ore handled an approximate estimate of the number of cycles of the loading which has occurred. Furthermore, the number of cycles of maximum stress per year is probably several times that of most railway bridges.

If reasonably reliable information could be developed on the magnitude of the stress and the number of cycles of the stress to which a given member has been subjected, an attempt could be made to interpret the fatigue performance of the actual members under service conditions in the light of laboratory fatigue tests on structural elements previously conducted at Purdue University and elsewhere.

The work of the investigation naturally fell into four parts, as follows:

1. Field studies on bridge No. 9 at the Gary Steel Works, Gary, Ind.
2. Field studies on bridge No. 2 at the Edgar Thomson Works at Braddock, Pa.
3. Survey and study of the history of fatigue failures in the ore bridges of the corporation.
4. Recommendations of measures to prevent fatigue failures in this type of structure.

ADMINISTRATION AND ACKNOWLEDGEMENTS

This was a cooperative project, and the forces of the university had the full and close cooperation and assistance of those of the corporation at all times.

For the United States Steel Corporation, the work was administered by Mr. C. E. Webb, chief engineer of the American Bridge Division, and was under the direction of Mr. V. D. Beard, assistant to the chief engineer, assisted by Mr. A. S. Marvin, division engineer at Pittsburg, and Mr. A. P. Boysen and Mr. W. K. Greene, division engineer and assistant division engineer, respectively, at Chicago. At the Gary plant all operations were carried out under the direction of Mr. D. E. Wise, chief engineer. At the Braddock plant, operations were under the direction of Mr. R. E. Moughton, chief engineer.

At Purdue University the project was conducted in the Engineering Experiment Station under the administration of Dr. A. A. Potter, director and dean of engineering, and Prof. R. B. Wiley, head of the School of Civil Engineering and Engineering Mechanics. In June 1953, Dr. A. A. Potter retired as director of the Engineering Experiment Station and dean of engineering and was succeeded by Dr. G. A. Hawkins. In June 1954, Prof. R. B. Wiley retired as head of the School of Civil Engineering and Engineering Mechanics and was succeeded by Prof. K. B. Woods as head of the School of Civil Engineering. L. T. Wyly, research professor of structural engineering and head

of the department, was project director, and was assisted by M. B. Scott, associate professor of structural engineering, as associate project director.

On the field investigations a regular crew of bridgemen was on the job during most of the work, swinging scaffolds and staging, cleaning and grinding the steel, building operator's houses, moving heavy equipment, and assisting in many other ways.

The electrical department of the corporation constructed and maintained the event marker systems and furnished and serviced two motor generator sets required to operate the cameras, lights, charging batteries, soldering, grinding, etc. This crew also strung most of the wiring for the instrumental work.

The photographic departments of the corporation made numerous photographs of the bridges and the test operations. These departments also developed much of the film used in taking the experimental data on the project.

The corporation also loaned the Purdue staff the use of a modern film viewer which was used at Lafayette, Ind., in reducing all the data on films.

GENERAL PROGRAM

It has been generally understood among structural engineers that ore and materials handling bridges, regardless of ownership, are subjected to cyclic loadings which result in fatigue failures of structural members and other details. The American Bridge Division officials have, for a number of years, kept systematic records of such failures in the ore bridges of the United States Steel Corporation. It was found that, while such failures might occur at any point in the structure, certain members were found to be most often affected, such as the stringer hangers, diagonals, and connecting gussets in the cross frames and the upper chords and the upper web members of the main trusses and their connecting gussets. These officials also advised that the failure cracks in most cases passed through the end rivet holes in the connections.

The above locations of failures would be consistent with the view previously advanced by the authors[1] that fatigue failures in structural members are largely produced by, or at least directly associated with, a combination of large local tensile stress and strain concentrations varying over a wide range of magnitude and repeated many times. The cross frame members carry practically no dead-load stress but receive directly the full force of whatever load and impact are produced by the trolley. They thus probably carry a wider range of tensile stress than any other members of the structure. In the main trusses the top chords and the upper web diagonals suffer also a considerable range of tensile stress as the trolley moves from cantilever to main span and back.

It was agreed, accordingly, that this investigation would be limited to the study of the above members.

The field investigation program was comprised of a study of the deflections, stresses, and accelerations in selected members of No. 9 ore bridge at the Gary Steel Works, Gary, Ind., and a similar study at No. 2 ore bridge at the Edgar Thomson Plant at Braddock, Pa. The data were reduced later at Purdue University.

Data for the study of failures were obtained by first hand inspection of cracked members in the bridges, by reference to official inspection reports of the sponsor, and by direct testimony of company engineers. Arrangements for examining these data were made possible through the courtesy of the American Bridge Division officials. Due to time limitation, it was not feasible to complete this study before starting the field work, although this would have been desirable; hence both phases were carried on concurrently.

For purposes of organization the study will be discussed in four parts under the headings of Part 1, Part 2, Part 3, and Part 4.

[1] See list of references at the end of the report.

General elevation of American Bridge Division type ore bridge No. 9, Gary Steel Works, Gary, Ind.

Part 1

Field Investigation of Ore Bridge No. 9, Gary Steel Works, Gary, Ind.

INTRODUCTION

The first series of field investigations undertaken on the project was conducted on an ore bridge of the Chicago type. The particular bridge selected was No. 9 ore bridge at the Gary Steel Works at Gary, Ind. All tests were made under regular operating conditions, August 1 to September 28, 1952.

The photographs show general views of the bridge tested. Fig. 1 shows the sections investigated on the cross frame, while Fig. 2 is a line drawing indicating the location of the test sections on the bridge truss.

PURPOSES OF FIELD STUDIES

The purposes of the field studies were:

1. To determine the magnitude of the stresses set up by regular operating conditions in the members which had been most subject to fatigue failure.
2. To study the variation of the stresses across the section of the members and to ascertain whether or not any severe bending or local stresses were present.
3. To ascertain whether or not some unusual stresses occurred in the members, seen as those due to design of structure; to vibration, impact, bridge traveling down the track, or moving into skew; or other causes.
4. To assist in establishing the stress history of the member in question, i.e., to ascertain as closely as practicable the variations in stress with normal travel of the loaded trolley across the bridge and by observing operations to establish the approximate number of such loading cycles to which the structure had been subjected in its service life.

Ore bridge at Gary Steel Works, showing trolley on the cantilever arm.

PROGRAM OF TESTS

The general program of the field studies at Gary No. 9 ore bridge comprised:

1. Studies of deflection of the structure in a vertical plane under static and dynamic loading.
2. Measurement of static strains in selected members in cross frames and in main trusses due to the loaded trolley.
3. Continuous measurement of strains at different sections and in selected members of the main trusses during the movement of the loaded trolley across the bridge.
4. Measurement of strains in selected members of the main trusses due to shock loading which could be produced by such conditions as the following:
   a. Jerking a loaded bucket of ore as suddenly as possible from the ore pile.
   b. Dropping a loaded bucket of ore and then catching it as suddenly as possible.
5. Measurement of accelerations set up by above loadings.

INSTRUMENTATION

1. *Strain Gages*

Static and dynamic strains were gaged by means of SR–4 wire gages. Type A–16 gages (½ in nominal gage length, 500 ohm resistance) were used at the various gage sections on the main trusses except at LM–2. At this section Type C–1 gages (1 in nominal gage length, 500 ohm resistance) were used. On the cross-frame members and

on the stringers, various other Type A gages were used. In general these were 120-ohm gages ranging from ⅛ in nominal gage lengths to 1 in nominal gage length, depending on the location of the strain being gaged. An attempt was made to keep the gage-to-ground resistance as high as possible. This resistance was kept as high as 10,000 megohms where possible, with 2,000 megohms being set as the minimum value allowed. The maximum number of static gages used on a common ground was 10, and the maximum number of dynamic gages used on a common ground was 12.

The usual procedure of using Duco cement followed by a waterproofing treatment of petrosene wax was used at Gary and found to be quite inadequate for gages needed over a period of several weeks. When the wind blew from the furnaces toward the bridge, the blast furnace gases in the atmosphere tended to break down the gage-to-ground resistance quite readily. This was a considerable source of trouble. It was overcome largely by applying hot wax to gage and leads shortly before using them. This procedure melted the old wax and carried off the accumulated particles deposited by the gases.

At Gary all static strain readings were taken at night, and the dynamic strain data were taken in the daytime. However, at Braddock it was found that making both static and dynamic strain readings at night was advantageous. This minimized any errors due to transient temperature changes. In addition, it was found that the gage-to-ground resistance was much higher at night when the steel was cool.

2. Strain Measuring Devices

(a) All static strains were measured by a Baldwin–Southwark strain reader, Type L.

(b) A two-channel Brush recording oscillograph was used to measure some dynamic strains at Braddock. These strains were in addition to those at the gage sections and were used as a partial check on the data gathered by the 12-channel instrument.

(c) All dynamic strains were recorded on the Purdue 12-channel oscilloscope. This instrument was designed and built by Prof. A. D. M. Lewis of the structural staff at Purdue and was described in Electronics.[4] Strains are detected by means of resistance strain gages and are indicated by 2BP11 cathode-ray tubes. The cathode-ray tube spot deflections are recorded by 35-mm film cameras. These cameras are capable of film speeds of 2 to 70 ft per sec. Two cameras are used, and 6 tubes are recorded by each camera. Reference lines are produced by argon glow lamps which are mounted between the cathode-ray tubes. A reference line adjacent to each trace is desirable because an analysis of the record made by a particular tube involves measurements which extend over only a small portion of the film width. Since the reference line is fixed in relation to the cathode-ray tubes, any movement of the cameras relative to the cathode-ray tubes or any lateral movement of the film as it passes through the camera has no effect on the accuracy of the results obtained. The reference lines are also made to serve as time scales by blanking the argon lamps at intervals of 1 and 10 milliseconds. Viewing of the film and measurement of strains may be accomplished by means of a microfilm reader such as are found in most public libraries.

Plug-in amplifiers with essentially uniform response over the frequency range of zero to 50,000 cps are used for amplification of the strain-gage signals. Other amplifiers may be substituted for use with suitable transducers for the measurement of quantities other than strain. For example, in the Gary tests other amplifiers were substituted and deflections were measured by means of Schaevitz linear variable differential transformers.

For each channel a calibration signal is produced by shunting one arm of each gage bridge circuit with a resistor. This calibration signal can be recorded by each channel at the beginning of a test run.

3. *Deflections*

Continuous records of deflections as the trolley moved across the span were made. These deflections were gaged by means of linear differential transformers whose output was fed into special amplifiers designed to be used with the Purdue 12-channel oscilloscope. The deflection data were recorded on 35-mm film in the same manner as the strain data. Because of the limited range of these transformers a special mechanical leverage device was used to scale down the bridge deflection movement. The lever arm of the device was fastened to a wire anchored at the stock pile of ore below and fastened at the upper end to spring balance scales held on a bridge member.

Deflections of the truss were also measured instantaneously by surveying instruments for several trolley positions.

4. *Trolley Positions on Bridge*

At both Gary and Braddock, an event marker system was used to indicate on the film the exact position of the trolley on the bridge at frequent time intervals. When the west end of the trolley passed a certain station, contact of the copper plate was made with a wire "whisker" mounted on the bridge station and a black spot was registered on the films in the cameras.

5. *Accelerations*

Acceleration measurements were made with 4 piezo electric crystals used in conjunction with two 2-channel Brush recording oscillographs.

A very substantial instrument house, built of steel and thus electrically shielded, was built especially by the American Bridge Division on the bridge at the east tower for this project.

The location of the sections of the cross frame and the truss members investigated is shown in Figs. 1 and 2. The gage locations at these sections are shown in Figs. 10 to 12, and 17 to 30, incl.

TROLLEY LOADING

The trolley loadings as given in the design plans are shown in Fig. 3.

DEFLECTION OF STRUCTURE

The purpose of the deflection study was to ascertain whether the vibration of the structure in a vertical plane would set up stresses of a significant value and whether resonance was likely to occur. The deflection measurements are summarized in Figs. 4 to 8, incl.

As a check on all other deflection measurements, readings were made with surveying instruments, as recorded in Fig. 4. Since the trolley was always on the structure, it was impossible to start with a no-load base line. Accordingly, it was decided to take as a zero line, to which all other deflection measurements would be referred, the position of the bridge when the trolley with empty bucket was at the center of the west tower, and the span was at 90 deg to the tracks on which it traveled. It should be noted that this reference or zero line was not a continuous straight line, since with the trolley at the center of the west tower, the trolley load was eccentric to the center of the tower truck by 4 ft, thus inducing a moment in the main truss at this point, causing some deflection downward of the west cantilever arm and also, to a lesser degree, deflection upward of the main span and downward of the east cantilever arm (See sketch "a" in Fig. 4). This zero line is shown in all deflection diagrams.

In Fig. 4, readings beside an observer's name are those made with the instrument. Levels and rods were used at the tower bases, and transit readings on steel tapes were made at the ends of the span. Other figures shown are computed from the foregoing on the assumption that both the zero line and the line showing readings with the trolley at the east tower were straight lines.

In Fig. 5, influence lines for the deflection of panel points L_0 and L_{25} are given. These deflections were measured with differential transformers located at these panel points. These influence lines represent the normal deflection under moving loads as measured from the zero line. Check readings by surveying instruments are shown as points A for static loads and points B for moving loads, the latter being the maximum which occurred under impact and vibration.

The influence lines for deflections of points 4 ft on either side of the center line of the tower truck near panel points L_7, L_8, L_{16}, L_{17}, are given in Fig. 6. These figures are for moving loads. Readings were taken with differential transformers.

An influence line for the angle of rotation of the east tower at the plane of L_{16}–L_{17} of the truss is given in Fig. 7. The loading is static. Readings were taken with a surveyor's level on scales mounted on the main truss at L_{16} and L_{17} as the trolley moved across the bridge.

A graph in Fig. 8 shows the deflection of the bridge at various points due to the trolley with a loaded bucket at L_{23}. The loading is dynamic, the maximum trolley speed being given on the stress sheet as 850 ft per min.

STATIC STRESS MEASUREMENTS IN FRAME AT POINT 18

To properly study and evaluate the measured stresses and to compare them with the design stresses, it is necessary to know the weight of the loaded trolley. This could be most easily and directly done by measuring the axial load in a stringer hanger while it supported the trolley. There was another reason for investigating the stresses in the cross frame; frequent failures have occurred in the stringer hangers, in the gussets connecting the hanger to the cross frame diagonals, and in the diagonals.

A theoretical analysis of the cross frame at panel point 18 is given in Fig. 9. The following assumptions were made:

1. The reaction delivered to the hanger bracket by the stringer is computed on the basis of a stringer continuous over four truss panels loaded with the assumed trolley weights shown in Fig. 3.
2. The horizontal lateral bracing in the plane of the top of the stringer will hold the bracket, where it joins the main truss vertical, against movement outward.

Measurement of static stresses in the stringer hanger and other supporting members of the cross frame at point 18 was made with the middle axle of the loaded trolley located at this point, as shown on Fig. 13. The results of these measurements are given in Figs. 10, 11, and 12, and summarized in Fig. 13.

DISCUSSION OF TEST RESULTS: CROSS FRAME AT L 18

Comparing the theoretical analysis in Fig. 9 with the measured stresses in Fig. 13, the following is clear:

1. The measured axial stress in the hanger of 141 kips checks closely with the value of 143 kips obtained by using the assumed trolley loads shown on Fig. 3. These loads are for a total weight of loaded trolley of 372 kips. The computed hanger stress obtained by using a total loaded trolley of 380 kips, would be

151 kips. It thus appears that the field stress measurements on the hanger and cross frame members check the assumed weights. This would be good evidence that the 380 kips assumed for loaded trolley is ample or perhaps a little high. It also indicates that the first assumption made above is about right.

2. The measured axial stress of 11 kips in the brace is only about one-third as large as the computed stress of 29 kips.
3. The measured axial stress of 180 kips in the diagonal is larger than the computed stress of 169 kips.
4. If the measured stresses in the hanger and the brace are used to compute the stress in the diagonal the result agrees with the measured diagonal stress.
   It is evident from the above that the second assumption made in the analysis is in error and that the elastic deformation of the horizontal bracing is sufficient to permit an outward movement which will reduce the stress in the brace without materially affecting the hanger stress.
5. The stress in the hanger in this frame can be closely computed by taking moments about the intersection of the brace with the center line of the bracket, neglecting the moment in the bracket at this moment center.
6. For this frame the vertical component of the stress in the brace is approximately 0.50 *(H–R)*, where *H* is the hanger load, and for design purposes the frame could be analyzed on this basis.
7. With the trolley located in the east tower, the measurements indicated there is a small amount of compression set up in the hanger, undoubtedly by the continuous action of the stringer.
8. The maximum unit stress in the hanger at the gage section, about 12 ksi, is not large. (See Fig. 10). There is considerable bending stress in the hanger even at this section, which was located near the center of the member, (see Fig. 1). It may be larger at the ends.
9. The principal tensile stresses in the gussets computed from the rosette measurements are not large, being about 15 ksi. Neither is the maximum shear of about 9 ksi large. (See Figs. 14 and 15).

The lowest rivet in the connection of the gusset to the upper end of the hanger was removed and gages placed at the sides of the hole. The measured strains would indicate a stress of about 30 ksi with the trolley centered at L–18. (See Fig. 16).

STATIC STRESS MEASUREMENTS IN THE NORTH MAIN TRUSS

It was desirable to take static readings on a number of members for several reasons:

1. To check measured stresses against the design stress sheet values.
2. To check measured stresses against values independently computed by the Purdue University staff.
3. To serve as a basis in evaluating dynamic stresses.

On Figs. 17 to 21, incl., there are plotted graphs of the computed total stress in the members tested for various locations of the trolley from L_{23} to L_{12}, and on these graphs are also shown the measured total static stresses for the trolley located at L_{23}, L_{19}, L_{18}, center of east tower, and at several panel points in the main span. In Table 1 there is given a comparison of measured static and dynamic stresses with the stress sheet values and with stresses for live load without impact as computed by the Purdue University staff. The stress sheet values include impact taken as equal to the stress given by 12 kips

acting on each of the 2 wheels of the trolley immediately over the bucket. (See Fig. 3). On Fig. 22 there are plotted experimentally determined stresses at two sections on U_{17}–M_{18} and U_{18}–M_{19}.

DISCUSSION OF STATIC TEST RESULTS IN THE NORTH MAIN TRUSS

The sections investigated were purposely located far enough away from the gussets to be free of the local effects of the rivet loads in the connections. It will be observed that the static measurements show a nearly uniform distribution of stress across the section where measurements were taken about half way along the length of the member, i.e. in DC–1, DC–3, DC–5, DC–7, and LC–1. A small amount of bending in the vertical plane is observed where the measurements were taken nearer the gussets; i.e., in DC–4 and DC–8.

It will also be noted that the measured stresses are generally greater than computed values for the diagonals, for some positions of the trolley quite a lot greater, and are greater for some trolley locations and less for other trolley locations in the lower chords. For the trolley at L_{23} the measured stress in L_{18}–M_{19} is 72 percent greater than the computed stress. (See Fig. 20). However, when the maximum stresses which occur in these diagonals are considered, the over run of the measured stress above the computed is only about 10 percent. Since it has been established above that the actual trolley weight probably was about the same as that assumed on the stress sheet, or at least did not exceed it, we may conclude that this over run is undoubtedly due to the participation axial stress carried by the rail stringer. Confirmatory evidence is the fact that whatever axial stress the stringer carries is acting in the direction to produce such over run.

The discrepancy between measured and calculated stress in chord L_{17}–L_{18} is also interesting. With the trolley at L_{23} the measured stress is about 12 percent less than the calculated stress. With the trolley at L_{19} the measured stress is about 68 percent larger than the computed stress. (See Fig. 21). Again the participation axial stress in the stringer acts in the direction to produce these discrepancies.

Fig. 22 gives a check on the spread of results in the static strain measurements. Sections DC–3 and DC–4, located on the same member at stations 11 ft apart, show total measured loads in member U_{17}–M_{18} of 120.9 kips and 118.5 kips, respectively. The measurements at these two sections were taken a week apart. Sections DC–7 and DC–8, also on the same member and 11 ft apart, show total measured loads in member U_{18}–M_{19} of 111 kips and 106.2 kips. These stresses were measured simultaneously. This spread of about 5 percent in results of static readings with wire gages under field conditions is common experience.

Fig. 22 also furnishes a check on the variation in bending along the lengths of these members. In U_{18}–M_{19} the static bending stress is about 9 percent at mid-length, and 4 ft 2 in from U_{18} it is about 14 percent. In other members the bending is at a smaller percentage.

DYNAMIC STRESS MEASUREMENTS ON NORTH TRUSS

It was considered desirable to obtain a continuous record of strain readings and variations as the loaded trolley moved across the bridge for all of the sections shown in Fig. 2. The signals from 12 channels were recorded on two 35-mm films by the recording oscilloscope described earlier in this report. It was essential that a calibration signal, under zero stress conditions, precede and follow each stress run record as closely as possible. The procedure adopted as a standard was as follows:

1. Trolley in west tower. Record calibration signal for each channel on the films. Start at zero time. Time elapsed at completion from zero time: 2 sec.
2. Trolley proceeds to the east end of the bridge, as near L_{24} as practicable in the shortest time possible. Time elapsed at completion from zero time: about 57 sec.
3. Stress run starts when trolley leaves L_{24} and moves west. Time elapsed at completion from zero time: about 57 sec.
4. At end of stress run trolley proceeds to west tower again and a final calibration signal is recorded. Time elapsed at completion from zero time: about 72 to 82 sec.

Each film was 100 ft long and usually recorded the results of one run. The cameras were shut off except during the calibration or during the stress runs. The films were developed within 24 hr and inspected for any information lacking.

The work of reducing the data consisted of the following:

1. The location of the trolley on the bridge at a given time with reference to panel points was marked in India ink on the film, using event marker data.
2. Using a film viewer, which magnified the 35-mm film about 15 times to a width of some 23 in, the data on the recorded traces for the individual channels were measured with a decimal scale and plotted on time scale graphs along with the calibration signals and the zero lines.
3. These graphs, representing a continuous record of the strain measured at each gage, were studied and the values plotted for the instant of time at which the maximum stress occurred.

The above experimentally determined stresses under dynamic loadings are shown in Figs. 23 to 29, incl. The stress in the member is labeled tension or compression and the total value in kips is given beside the diagram showing variation of stress across the section. The figure also shows the position of the trolley for the stresses shown. Where static stresses had been taken they are also shown.

DISCUSSION OF TEST RESULTS FOR DYNAMIC LOADS ON NORTH TRUSS

The experimentally determined stresses for live load plus impact show the same general pattern, at a given station, as the measured stresses for static loading. No evidence of unusual impact or high bending stresses was found. If impact is defined for convenience as the excess of measured total stress in the member due to dynamic loading over the total stress due to static loading, the percentages of measured impact for these members vary from 11 to 37. (See Table 1). The impact assumed by the designer, as shown in the stress sheet, was about 14 to 16 percent for the members in question. No high stresses were found. The highest experimentally determined unit stress due to dynamic loading in a compression member was 9.6 ksi in L_{18}–M_{19}; the highest unit stress in a tension member was 11 ksi in U_{18}–M_{19}. (See Figs. 25 and 26, respectively). These were total combined unit stresses due to axial load plus bending. Bending in the transverse plane was found to be remarkably small.

The maximum measured axial unit stress in tension was about 9 ksi on the gross area, in U_{18}–M_{19} at section DC–7. (See Fig. 26). The maximum measured axial unit stress in compression was about 7.6 ksi in L_{18}–M_{19} at section DC–7. (See Fig. 25). Most of the measured unit stresses were well below these. The measured live load plus impact stresses run a little over those shown on the stress sheet in most cases. This over run

varies from 6 to 14 percent. In two members, M_{15}–L_{16} and M_{15}–U_{16}, the measured live load plus impact stress is less than that shown on the stress sheet.

The foregoing thus leads to the conclusion that the members are well proportioned and quite conservatively designed.

DYNAMIC STRAIN AND DEFLECTION MEASUREMENTS IN NORTH TRUSS

It was thought necessary to check the amplitude of the vibration in the vertical plane of the bridge under regular operation and to determine the amount of stress variation resulting from this action. For this purpose a number of runs were made where stress and deflection were measured at certain points simultaneously.

The amplitude of vibration of the structure as a whole was found to be small. The difference between the static and dynamic deflections shown in Fig. 5 is a good index to this amplitude. For point L_{25} with the loaded trolley located at L_{24}, the dynamic vibration gave deflections from the zero line of about 5.75 in. With loaded trolley at L_{22} the dynamic deflection was 4.71 in. The corresponding static deflections from the zero line at point L_{25} were 5.12 and 3.88 in. These increases of dynamic deflection, in the order of 11 to 22 percent, are a good index to the effects of vibration found. They are of the same order of magnitude as the measured stresses due to impact. The frequency of these vibrations was about 1¾ cps. Finally, no significant resonance of truss deflection was found.

DYNAMIC STRESS, DEFLECTION, AND ACCELERATION MEASUREMENTS CORRELATED

It was thought desirable that direct measurements be made of any accelerations which might be acting at the truss panel points during dynamic loading or vibration, and that such measurements be correlated with those for simultaneous stress in selected members and deflections at the panel points.

Four piezo electric crystal pick-ups were mounted so as to record accelerations in the vertical plane at panel points L_{25}, L_{23}, L_{21}, and L_{19} simultaneously with the placing of differential transformers at these same points and also at L_0 and L_7. Later the crystals and transformers at L_{19} and L_{21} were transferred to L_{12} and L_{14}. The signals from the crystals were recorded by the Brush oscillographs. Six channels of the 12-channel oscilloscope were used to record truss deflection. The other 6 were used to record measured strains in U_{17}–M_{18} and later in U_{18}–M_{19}.

The test operations consisted of a number of runs where a loaded bucket of ore was suddenly jerked off the ore stock pile and hoisted as fast as possible by the operator, or where a loaded bucket was dropped from a position just beneath the trolley as freely as possible and was then snubbed or jerked to a standstill as suddenly as practicable. In some cases after one of the above operations the operator held the trolley stationary on the bridge. In others he caused the trolley to proceed as quickly as possible to the east tower and held it there.

The instruments worked satisfactorily for the most part and recorded the resulting deflections, accelerations, and stresses, but the magnitudes of the additional quantities measured (due to this dropping or lifting of the load) were not great enough to be significant.

The reason for the small magnitudes of these additional quantities lies in the relative values of the loads involved:

Weight of trolley without ore .....336 kips (or 88.5 percent of total)
Weight of ore ..... 44 kips (or 11.5 percent of total)

Total .....380 kips

From this it can be seen that acceleration forces due to stopping or starting the ore would have a very small effect in setting the whole mass of trolley plus ore into motion.

STRESSES MEASURED IN THE CONTINUOUS TROLLEY STRINGERS

Many fatigue failures have been reported in the trolley stringers of the ore bridges. In the cases which were brought to the attention of the authors these cracks started at or very near the fillets under the upper flanges at the panel point supports. In most cases the stringers are continuous at the supports. It had been agreed that a study of this matter would not be included in the investigation for two reasons: (1) it is a special problem, and (2) it was felt that a correct analysis had been made and a satisfactory solution arrived at by the American Bridge Division engineers. However, the latter requested that some measurements be taken at the points in question. The results of these measurements are given in Fig. 30.

In all cases the strains were measured in a vertical direction only. Due to time limitations no attempt was made to use rosettes or to measure stresses in the direction of the length of the beam. Hence the true stress at gage 22 under the passage of wheel 4 will probably be something less than the product of 30,000,000 by 0.001. A close approximation could be made by taking into account the bending stress computed in the longitudinal direction and the shear stress for a beam continuous over level supports at the truss panel points. All measurements were taken under static loads.

It will be noted that a very severe bending stress is set up in the web of the beam at the fillet at the supports for this loading.

When the range of strain which occurs at the fillets in a direction normal to the cracks every time the trolley passes the point is considered, it is plainly not difficult to account for the occurrence of these fatigue failures.

SUMMARY OF EXPERIMENTALLY DETERMINED STRESSES IN THE NORTH TRUSS

1. The evidence collected indicates that the weight of the fully loaded trolley in operation during the investigation here reported was not in excess of that assumed by the designers in making the stress sheets. (See Fig. 3).
2. The discrepancy between experimentally determined stresses in the truss members and the stresses computed for the same loading by conventional methods as listed in Table 1, is undoubtedly due to participation stress carried as an axial load by the rail stringers. For the web members studied this situation results in a small increase of the actual maximum stress due to live load plus impact carried by the member. For the lower chord member, L_{17}–L_{18}, the result is a decrease in maximum live load plus impact stress. It probably produces an increase in the top chord stresses where the centroid of the stringers is higher than that of the lower chords.
3. It is desirable that a method of analysis be developed which will yield stresses agreeing more closely with those actually occurring in the trusses of the bridge by taking into account the participation stresses carried by the trolley stringers. When this has been done, the stresses in top chords should be checked by the new procedure.

4. No high or alarming unit stresses were found. The stress is rather uniformly distributed over the cross sections and no evidence of high local bending was found. The bridge was found to be excellently and conservatively designed at all points studied.
5. No evidence was found of high-speed stress transients or sudden impact stresses of any appreciable magnitude.
6. Omitting consideration of any unusual stresses due to gross mishandling, such as allowing the trolley to run full speed through the limit switches and into the bumpers, allowing the bridge to run at full speed down the track and into the track bumpers, using the bridge to tow loaded railroad cars on tracks below by lines engaging the free end of the main cantilever spans, etc., no stresses were found which could account for fatigue failures. The cause of such failures must rather be sought in the conditions of stress and strain at the precise points of initiation of the fatigue cracks, i.e., at the sides of the rivet holes.

Part 2

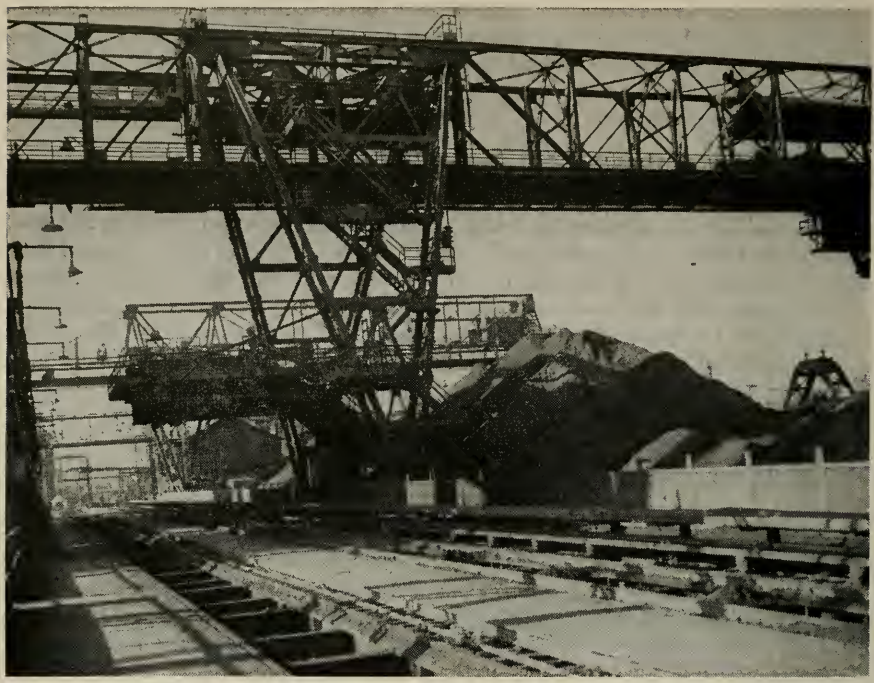
Field Investigation of Ore Bridge No. 2, Edgar Thomson Steel Works, Braddock, Pa.

INTRODUCTION

The second series of field investigations undertaken on this project was conducted on an ore bridge of the Hoover–Mason type. The particular bridge selected was the No. 2 ore bridge in No. 1 ore yard at the Edgar Thomson Steel Works at Braddock, Pa. Work was started at the bridge site on June 15, 1953, and all tests were completed by July 31, 1953.

The photographs show two views of the structure, while Fig. 31 is a line drawing diagram showing its dimensions and general configuration. Also shown in Fig. 31 are the locations of the 15 test sections selected for study in this investigation.

North elevation of Hoover–Mason type ore bridge No. 2, Edgar Thomson Steel Works, Braddock, Pa.



South elevation of Hoover–Mason type ore bridge No. 2, Edgar Thomson Steel Works.

OBJECTIVES AND PROGRAM FOR FIELD TESTS

The primary objectives of this field investigation were:

1. To obtain a quantitative measure of both static and dynamic live load stresses existing in selected members of the ore bridge structure due to regular operations of the loaded trolley. This information would yield a true picture of the stress variation existing in the member due to service loadings. These observations included data taken in the normal and skewed positions of the bridge.
2. To obtain a quantitative measure of the variation of stress across the sections to ascertain whether or not any severe local bending stresses were present.
3. To ascertain whether or not some unusual stresses occur in the members due to design, vibration, impact, skewing, suddenly dropping or suddenly raising the ore bucket, or other causes.
4. To determine the natural frequency of the structure vibrating both horizontally and vertically and to correlate this with live-load stresses set up in the members.

Uncertainty as to just how the structure was performing as a space framework dictated in large measure the testing program adopted. In general, the tests were aimed at establishing a quantitative measure of the stresses set up in the members of the structure due to action of the live loads. This included stresses due to usual operational conditions as well as those due to impact, vibration, skewing, or any combination of such effects

as were liable to occur. With this definite information as a base from which to work, the study of the causes of failure could proceed.

Several standard test procedures were used to provide this information. To represent an average operational run, the trolley picked ore from the receiving trough and then moved with its load to the furnace end. This represented the longest probable trolley travel during ordinary operations and was quite typical of the operations as observed. To investigate a possible extreme loading condition, eight of the dynamic runs were made in which the operator, with the trolley stationary at mid-span, picked a load and started the bridge moving along the ore pile all at the same time. This was done in as quick and jerky a manner as the operator could manage. It was believed that these two cases represented the extreme load conditions which may be realized with more or less regularity in this type of structure.

Static strain measurements were made at each of the 15 gage sections. These measurements consisted of measuring the strain (from which stress and total load in a member could be computed) set up in the test members when the loaded trolley was placed in the position causing maximum or minimum total load in the member under consideration. The positions of the trolley used in making these measurements were established from a record (made with a two-channel Brush recording oscillograph) of the actual stresses occurring at the section as the loaded trolley moved slowly across the span. From this record the critical positions were accurately determined. These static readings served to establish the basic pattern of actual stress distribution over the cross section of each of the members. This static distribution was then compared to the distribution measured by the same gages under dynamic loading conditions. A total of 36 dynamic runs and 16 acceleration runs were made in gathering this performance data on the members under consideration. The summary of this data is presented in Figs. 32 to 56, incl., and Table 2 of this report.

In addition, some stop watch and transit observations were made to establish the vibrational frequencies and vibrational amplitudes of the movement of the structure during operational runs.

On the basis of the results obtained, this survey seemed adequate to establish the general pattern of performance for all members of the bridge.

INSTRUMENTATION

For measuring static and dynamic strains, SR–4 wire gages were used. Type A–16 gages (½ in nominal gage length, 500 ohms resistance), were used at each gage section for measuring the static and dynamic strains. The locations of these gages at the various sections under consideration are shown in Figs. 32 to 56, incl. In addition to the gages shown in these two figures, two Type A–5 gages (½ in nominal gage length, 120 ohms resistance) were used at each section. These two gages were placed as close to the gage section as practicable. They were mounted one on each side of the member, along that center line of the cross section lying in the plane of the truss. These two gages served to make possible simultaneous readings at each section with two different measuring devices. The Brush recording oscillograph was used with these special gages, giving a "monitoring" device for limited checking of the more detailed information being obtained.

The extremely corrosive nature of the atmosphere around the blast furnaces at Braddock made the installation and protection of the strain gages a particularly critical job. After proper cleaning and grinding of the surface of the steel at the gaging stations, the SR–4 gages were attached to the steel by means of Epon resin cement. Duco or other standard adhesives were adversely affected by the atmospheric gases, so it was necessary

to use resin. The Epon was protected by an aluminum-foil covering during initial setting. After several hours the foil coverings were removed and the cement was cured for several hours by use of heat lamps. Once the curing was complete, the gages were given a waterproofing treatment consisting of hot petrosene wax followed by several layers of a brushed-on covering of a special liquid neoprene rubber compound. This procedure yielded very satisfactory results.

Strain measurements were made by three different types of measuring devices:

(a) *A Baldwin–Southwark Strain Reader Type L.* All static strains were measured by this L-Box, using the Type A–16 gages as strain pick-ups.

(b) *Brush Recording Oscillograph.* This is a low frequency (good up to about 100 cps), direct recording, two-channel instrument. It was used for all exploratory tests made to determine trolley positions to be used in the static test runs. It was also used simultaneously with the 12-channel oscilloscope during the dynamic runs. This arrangement provided a means to monitor or check the data taken during the dynamic runs. Type A–5 strain gages were used as strain pick-ups. This instrument served further in conjunction with piezo electric crystal pick-ups for measuring accelerations at various points on the bridge.

(c) *Purdue 12-Channel Recording Oscilloscope.* All dynamic strains, using the A–16 gages as pick-ups, were measured by this instrument with the results being recorded on photographic film.

The films upon which the dynamic data were recorded were developed and processed by the microfilming unit of the U. S. Steel Corp. at the Pittsburgh office. After processing, the film was given a preliminary check reading, using the microfilm viewers at the Pittsburgh office. Later it was taken to Purdue University for a final analysis of the complete run.

All measuring equipment was housed in an especially constructed metal instrument house located on the structure. Three-conductor shielded cable leads were used for both static and dynamic runs. These leads were run from the gages to the instrument house and connected to proper switching gear at that point. All strain measurements, both static and dynamic, were made at night to eliminate transient effects due to temperature fluctuations, and to secure maximum gage-to-ground resistance. It was observed that the gage-to-ground resistance was much higher at night when the steel was cool than it was during the day when the sun kept the steel at a fairly high temperature.

DISCUSSION OF TEST RESULTS

For each of the gage sections selected for investigation in this test there are two drawings available which summarize the data taken at that section. (See Figs. 32 to 56 incl.). For the three positions of the bridge there is shown the maximum and minimum stresses (computed from measured strains) which were found at that section under both static and dynamic application of the live load. The drawings for gage sections through the lateral bracing, sections XM–1 and XM–2, have been omitted in this report because this lateral bracing was found to be carrying very little load.

Before examining the individual drawings in any detail, attention is called to Table 2. This table briefly summarizes some of the data for the "span square" position of the bridge found on the individual drawings. In this table the computed and measured loads in the several members are compared. The computed values are taken from the design drawing stress sheet. The measured stresses in the same members are computed

from the measured strains. As a typical example you will note for member U_5L_6 the stress sheet live-load value is given as + 106 kips or — 9 kips. The measured values are shown as + 113.5 kips and — 5.6 kips at section DM–1 and as + 116.3 kips and — 4.0 kips at section DM–2. Thus the average measured value would be + 114.9 kips and — 4.8 kips. These measured values are about 8 percent higher than the computed stress. This close agreement seems remarkable. It would also suggest that perhaps the trolley wheel loads used in the design might be low by about 8 percent. Similar comparisons can be made for the other members shown.

The agreement between the measured and computed stresses can be seen to be very good except for the tower chord stresses. Here there is considerable variation due to real lack of definite information on the nature of the composite chord action. Thus it seems permissible to conclude that in general the design analysis assumptions were reasonable, and that substantial overloads were not present in the members of the structure.

An interesting sidelight is thrown on the action of "counter" members by the data given. Member U_6L_7 apparently was used as the main diagonal in panel 6–7 and its stress was computed as + 79 kips. The measured values indicate that the counter member, however, does not carry zero stress as assumed in the analysis, but that it actually carries some compression. However, the + 32.2 kips carried at section DM–3 and the — 46.6 kips carried at section DM–4 (both diagonals thus share the shear) gives a total stress on both of 79.8 kips. Under the other loading condition where the counter is assumed to take all the live load, its stress is computed as + 37 kips. Again the diagonals are both acting and the sum of DM–3 and DM–4 adds up to 37.3 kips. Thus the counters definitely assume their part of the panel shear at design loads even though they are assumed to be inactive when in compression. However, at ultimate loads the tension member would be carrying all the load, as the compression member would buckle at or near the yield point.

In general, the agreement between measured and design loads in members is well within reasonable limits of accuracy. In the members tested there is no indication of any abnormal overloads, thus verifying the design analysis procedures.

No attempt will be made to discuss in detail the data taken for each member tested. However, an examination of two typical members will serve to illustrate in a general way the conclusions which can be drawn from the data. On the summary sheet for UM–1 (Fig. 32), attention is directed to the following:

1. The stress distribution, both under static loads and dynamic loads, is uniform and reasonable. There appears to be no "racking" or other severe conditions causing abnormal stress distribution on the section.
2. The maximum stress range at any point in the member is in gage "b" on the web. Here the stress varies from 4410 psi in tension to 6000 psi in compression —a total stress range of 10,410 psi. Part 4 of this report comments upon the fatigue effects of this range of stress.
3. Examining the data given for the square and for the two extreme skewed operating positions of the bridge, it can be seen that the stress variations between the skewed and square positions are not large, but it does indicate there may be some small shifting of loads between the trusses due to these position changes. For example, the total maximum load in member U_5U_6 at section UM–1 in the skewed *west* position under static loading is 154,500 lb compression. In the skewed *east* position the load is 177,000 lb compression. In the *square* position this load is 171,200 lb compression—near the average

of the two extreme skewed positions. Thus it can be concluded that the operating position of the bridge, whether skewed or square, has only a small effect on the amount of total trolley load carried by each of the two trusses. If the square position is taken as a standard, it appears that instead of each truss taking 50 percent of the total trolley live load, the distribution might change to a 60–40 percent distribution between the trusses when operated in the skewed positions. This percentage distribution is not quite the same for all members, but the results in the members observed point to no drastic overloading of truss members due to the skewing operations of the bridge.

4. There is some evidence of small local bending action indicated by the fact that the stresses on the upper flanges are greater than those on the lower for maximum compressive load positions.
5. The impact percentage in this member for the maximum compressive load is about 13 percent in the cases shown.
6. The dynamic stresses for the minimum load positions are smaller than the static in this case due to the final trolley positions. Under static loads the trolley was moved out as far as possible on the cantilever arm. During the dynamic runs the operator stopped the trolley in his usual position for loading the transfer cars.
7. The total load, static and dynamic, in the member in the squared position is an average of about 12 percent larger than the live load tabulated on the stress sheet for this member.
8. The second drawing for this member (see Fig. 33) shows the effect of acceleration forces on the member when the bridge was moved along the track. The total combined stresses, due to direct trolley live load and due to acceleration forces caused by bridge movement, were found to be quite well distributed over the member. They were, on the average, about 50 percent higher than the maximum static live-load stresses for this member. This ratio does not hold for all members observed. It is usually smaller for web members than for chord members.

Similar comparisons for each member tested can be made upon examining Figs. 34 to 55, incl.

Attention should be directed also to the diagram on Fig. 56 showing the stresses found at section LM–1. This drawing shows quite graphically the participation of the stringer and floor plate in the lower chord stresses. The upper diagram, showing the stresses when the wheel is in panel 1–2, makes the phenomenon most clear. With the trolley in this position the stringer and floor plate should be unstressed. However, the gages show a uniform and planar distribution across the entire combination of truss member, plate, and stringer.

In the lower diagram of Fig. 58, where the stringer is carrying load in flexure, the combined action is again apparent. The measured stresses again show a planar distribution of stress across the entire section, indicating mutual participation of a whole combination of parts in their combined functions. A more complete run down of this phenomenon as the trolley moved across the span was investigated, but the results have not been included here because it is felt that the two diagrams shown are sufficient to illustrate the composite action found. In Fig. 57 the validity of this composite action as measured is indicated by applying a static equilibrium check to a section passed through panel 5–6 of the truss. Here you will note that the trolley is located out on the cantilever arm in panels

1–2 and 2–3. On the basis of the measured stress the lower chord member is carrying 91 kips, the walkway plate is carrying 36.4 kips, and the stringer is carrying 70.7 kips. The total load of the combination is 198.1 kips. Passing a cutting plane as shown in Fig. 57 and summing moments about indicated point A, one finds that the moments of all forces acting balance within about 1¼ percent. This seems to be an excellent check.

To obtain data regarding the longitudinal vibrations and natural frequency of the structure, observations with a stop watch and transit were made, yielding some information on this matter. The natural frequency of oscillation longitudinally was found to be about 1 cps. The vibrational double amplitude was about 2 in. in cases where the operation of the trolley seemed to be in resonance with the bridge vibration. In this connection it was noted that the longitudinal shift of the bridge as the trolley moved from the tower to the shear leg was about a total of 1 in toward the furnace end. This movement was recovered as the trolley moved back to the tower. These vibrations and longitudinal movements set up some oscillatory stresses in the bridge, but these did not seem to be particularly high. No quantitative data on this phenomenon are included here.

No quantitative conclusions regarding the inertia effects of raising and lowering the loaded or unloaded bucket can be set forth here. Accelerations as observed both in the vertical and horizontal directions were small and seemed to set up no excessive stress in the members. In all cases the accelerations measured were less than 0.1 *g*. This was so small that the results obtained were not significant, leading to the conclusion that stresses due to these inertia effects are generally negligible.

By comparing results of static runs it was concluded that it was possible to balance the trolley on the shear leg. This gave a condition approximating an unloaded condition of the bridge. Thus, all stress runs were considered as starting with a zero live-load stress, and all results are reported as total live-load stress, even though the trolley could not be removed to give a true zero condition.

CONCLUSIONS

The following represent conclusions gathered from the observed test data:

1. The stress distribution in the members tested was uniform, reasonable, and free from abnormal concentrations. The gage sections were taken far enough from the gusset plates and other details to give the picture of the stress on the gross section. No attempt was made to measure stress concentrations at gusset-plate rivet holes or at other such points of local concentrations.
2. The loads in most members, computed from the measured strains, were in good agreement with design loads shown on the stress sheet. (See Table 2). This seems to verify, at least in part, the method of analysis used. Notable exceptions were the lower chord members and the chord members in the tower. In the latter case there is a composite action which is not clearly defined.
3. The composite action of lower chord, stringer and walkway plate was measured and establishes the nature of this phenomenon. (See Figs. 56 and 57). The three components function jointly as a single member. It does not seem feasible to depend upon this action to carry the design loads of the lower chord, but it should be considered when determining the walkway plate rivet requirements.
4. The skewing of the bridge does cause some apparent shifting of loads between the trusses. The amount is not large, however, and does not seem to be the cause of any serious overloading of the truss members. (See Fig. 32 as typical case). About a 60–40 percent distribution of total load between trusses seemed to be typical.

5. The impact allowance for the dynamic effect of the live load varied somewhat with the type of member under consideration. Between 10 to 15 percent would seem to be an acceptable average for this allowance. (See Fig. 32 where the impact is about 13.6 percent).
6. The stresses set up in the members due to the movement of the trolley along the track while a load is being picked from the ore pile, are high enough to be a cause for some concern. The magnitude of such stresses varies with the member involved. The stresses in chord members were measured and found to be found to be as much as 50 percent, or more, higher than stresses due to maximum static live-load values. (See Fig. 33). The increase for web members was generally, but not always, smaller than this. It should be pointed out that this phenomenon was not investigated exhaustively. All such measurements were always made with the trolley at mid-span. No attempt was made to establish the critical location of the trolley for each member involved.
7. From stress measurements made with the Brush oscillograph, there was no evidence of any sizable stresses being set up in the members due to the movement of the bridge from the square to the skewed positions.
8. Oscillations of stress due to vibration of the structure both longitudinally and vertically are present in the structure. However, the magnitude of this oscillatory stress is small, being generally in the neighborhood of $\pm$ 1000 psi.

Part 3

Survey and Study of Fatigue Failures in Ore Bridges of the United States Steel Corporation

An essential part of this investigation was the collection, as far as practicable, of all available information on the history of fatigue failures in the ore bridges of the United States Steel Corporation. This consisted of the following steps:

1. Study of the records of past failures.
2. Field inspection of bridges where failures have occurred.

The officials of the American Bridge Division made available to the Purdue University staff the information in their records regarding the failures which have occurred in the past. In the Chicago region this information was largely supplied by the staff of Division Engineer Boysen from official records. Additional and valuable information was also obtained by study of the records in the South Works Plant offices, and from statements by Mr. Hughes, inspector in charge of ore bridges in this region. In the Pittsburgh region the information was supplied by the records of Division Engineer Marvin and from statements by Mr. Cunningham, inspector in charge of ore bridges in this region.

The records from these two offices differed in certain important respects. In the Chicago area the records indicated that the failures from fatigue began early in the service life of the structures and continued thereafter at an increasing rate. In the Pittsburgh area the records only showed these failures as occurring after many years of service of the structure. Since the beginning of rather complete records in each case coincided with the date that the inspection and repairs of the ore bridges was delegated to the American Bridge Division, i.e., about 1941, the question at once arises whether failures

have actually started earlier and have been more frequent in the Chicago area than in the Pittsburgh region, or whether the record is simply lacking in the latter case.

The only bridges for which the records available appear to be fairly complete are at the South Works, Chicago. General data on these structures are given in Table 3. Accordingly, it was decided to study the failures in these structures in as much detail as was practicable to see whether any failure pattern could be found which could be interpreted in the light of fatigue tests previously made in the laboratory. For any such study, it is essential to know the following:

1. Members which have failed and the year of failure.
2. Location of the failure crack in the member.
3. The precise point of initiation of the fatigue crack and its trajectory as it propagated.
4. As accurate an estimate as possible regarding the stress and strain concentrations present at the point where the crack was initiated.
5. The range of stress at the point of failure to which the member has been repeatedly subjected; also the state of stress.
6. The number of cycles of this range of stress which the member has endured before the failure crack became evident.
7. The properties of the steel from which the member was made.
8. The fabrication and erection methods used in construction.
9. Any unusual circumstances in the history of the member.

An attempt was made to obtain as much of the above information as possible.

Information regarding Item 1 was obtained from corporation records. It is summarized in Figs. 58 to 61, incl. These figures cover the north dock bridges. The only information available regarding the two south dock bridges was that a stringer diagonal at the south end of the cross frame at point 12 had cracked in 1951 in bridge No. 1. The south dock bridges were built in 1944 and 1943, respectively. The following pertinent observations may be made:

1. In 17 years of service life, bridge No. 2 has developed 21 fatigue failures in the main truss members and over 57 failures in the cross frame members. This structure leads the list in number of failures recorded.
2. In 25 years of service life, bridge No. 1 has developed at least 1 failure in truss members and 21 in cross frames. Since there is no record of repairs for the first 13 years of the life of the structure, it is quite possible and even probable that many unrecorded failures have occurred.
3. In 13 years of service life, bridges No. 3 and No. 4 have developed 12 and 3 truss failures, respectively, and each, one cross frame gusset failure.
4. In 7 years of service life, bridge No. 1 of the south dock developed one hanger failure.

A summary of the data on the fatigue failures in four bridges in the Pennsylvania and Ohio regions, as furnished by Messrs. Beard and Marvin, is shown on Figs. 62 to 65, incl. The failures show the same general pattern as was exhibited in the South Works bridges, but as far as the record indicates, these failures took place after many years of service.

The above is an impressive list and highlights the importance of the problem.

Information regarding Item 2, the location of the failure cracks in the member, was obtained initially from Inspectors Cunningham and Hughes and was verified later

by field inspection. Early in September 1952 and again in June 1953 Mr. Hughes conducted Messrs. Wyly, Scott, and Prince on an inspection of the north dock bridges. During the first of these visits, Mr. Hughes was able to point out a number of existing cracks in the cross frame members of bridges No. 1 and No. 2 and said that these illustrated a regular pattern for failure in these members. This information was later put on sketches for his inspection report and is reproduced, with the permission of the corporation officials, in Figs. 66, 67, and 68.

At the time of this inspection no cracks were to be observed in the main truss members. On the second visit, Mr. Greene, assistant division engineer, Western Division, furnished Messrs. Wyly and Scott with copies of inspection sketches made by Mr. Hughes, showing the location of some typical fatigue cracks in the chord members. These are reproduced in Figs. 69, 70, and 71. Significance is attached to the following facts brought out by the study of the above information:

1. All the cracks start at the side of a rivet hole. This includes the cracks in the gussets.
2. In the cross frames and the truss web members, the cracks always start at the sides of the rivet holes at the edge of the gusset or splice plates. (See Figs. 66, 67, and 68). In the gussets the cracks start at the sides of the rivet holes at the ends of the members. (See Fig. 66). In the chords the cracks may start at the sides of the hole containing the last rivet at the edge of the gusset (see Fig. 70), or they may start at the rivet hole nearest the edge of a stay or batten plate on the lower flange, or at the connection of a lacing bar, also on the lower flange, or they may start at the end rivet in a bar splicing the outstanding lower flange at the joint. (See Figs. 69, 71, 72, and 73). It is significant that no failures have been reported as occurring in the top flanges of the top chords. A number of other reports supplied by the offices of Division Engineers Boysen and Marvin show failure cracks originating at the same places in the members, in other bridges.
3. The maximum stresses in the members or gussets in which the cracks occur are not high. In no case reported was the computed unit axial stress over 17 ksi, and in many cases it was 13 ksi or less.
4. In any given structure, of the total members subjected to a similar loading an equal number of times, more members do not fail than do fail.
5. Cracks in the stringer hangers and in many of the web members of the trusses appear always to start at the upper connection.

The information listed under Item 3, the precise point of initiation of the failure crack and its trajectory, can only be determined by a close visual inspection of the crack or from a good large scale photograph of it. Since this information reveals much regarding the type of local stress which gave rise to the crack formation, accurate information on this matter is of the greatest importance to the understanding of the problem. At the time of the September inspection noted above, it was possible to trace some of the cracks a certain distance under the rivet heads and to see that they originated at the sides of the holes, but a little distance, about 3/16 in, above the center line of the hole normal to the member, on the bearing side of the rivet. It was also possible to establish in the cases inspected that the crack proceeded away from the side of the hole, not in a straight line at right angles to the member, but in a slightly curved path, somewhat concave, toward the above noted transverse center line of the hole.

Any accurate estimate of the stress and strain concentrations present at the point of crack initiation is difficult and must be based on laboratory studies of similar conditions. However, it must start with a study of the shop details and the processes of manufacture. The shop details tell where stress and strain raisers, due to form factors, may be located. Such are rivets and rivet holes, small edge distances, sharp cuts, notches, etc. The processes of manufacture give some clew to probable presence of stress and strain raisers due to punching or drifting, welding, etc. The most obvious source of such concentrations may be listed as:

1. The presence of the rivet hole itself.
2. The bearing of the rivet on the metal of the hole.
3. Eccentric bearing caused initially by the single lap type of connection, permitting the rivet to rotate and bear on the edge of the hole as slip between the gusset plate and the main material occurs.
4. Very small initial cracks, induced by full-sized punching, at the sides of the holes in the main material used for connection of lacing or stay plates.
5. Very small initial cracks at the sides of reamed holes in the main material due to drifting during shop or field assembly.
6. Irregular scratches or gouges, not always so small, in the metal at the sides of the hole which sometimes occur when the drills or reamers are not sharp.

It is noteworthy that most of the reported fatigue cracks in the truss chords occurred in the lower flanges and that a considerable percentage of these were at the sides of full punched holes used for lacing or stay plate connections. Figs. 72 and 73 show typical failures through punched holes in web members. Failures in lower flanges of the top chords occur similarly. Failures were also reported through these lower flanges at the end rivet in the splice bar near the joint. (See Figs. 69 and 71). The crack in the channel web in Fig. 70 illustrates another location of top chord failure. It is significant that no failures in the top flanges of the top chords have been reported. The rivet holes in these flanges were all sub-punched and reamed.

To estimate accurately the range of stress in a member, there is required a knowledge of:

1. The weight of the loaded trolley.
2. The actual stresses which the loaded trolley will set up in the member.
3. The impact or dynamic augment of stress to be expected.
4. The normal and regular travel of the trolley in handling ore, cinders, etc.

To estimate Item 6, the number of cycles of the maximum range of stress to which a member has been subjected, it is necessary to know:

1. The total tonnage of material handled by the bridge in its service life.
2. The number of trips made by the loaded trolley over the portion of the span which will produce the range of stress in question. The latter may vary with the member in question.

Mr. Moughton has supplied the information on the tonnage handled during the life of bridge No. 1 at Braddock and an estimate of the total number of round trips made by the trolley. Mr. Greene has supplied similar information for bridges No. 8 and No. 9 at Gary and for the north dock bridges of the South Works. The total tonnage for these latter bridges is given in Fig. 74. Mr. Greene's letter of May 14, 1954, stated:

"The tonnages on the attached sheet are approximate. The tonnage of stone and ore handled per bridge was proportioned from the total received at the north dock for each year listed.

"The trips as presented are assumed round trips of the trolley from the loading trough to the high line. In calculating the number of round trips per bridge, it was assumed that each trip transferred the rated capacity of material for the ore bucket and then 10 percent was added."

Since a considerable amount of information on the failures in the north dock bridges is at hand, the attempt to estimate the location of these failures on a S–N diagram was made. The failures may be divided into two classes according to the range of loading to which the members had been subjected:

1. A stress range of zero, or perhaps from 1 to 2 ksi, up to a maximum tension stress. This loading applies to the stringer hangers and cross frame members.
2. A stress range varying from initial low tension, or even compression, up to a maximum tension stress, or perhaps the reverse. This loading applies to the truss members, particularly the upper chords.

The cross frame member failures have been studied first since it is felt that the necessary information is more complete for them than for the failures in truss members. Using the stress measurements on the Gary bridge cross frame as a guide, the axial stresses in the typical hangers and diagonals of the cross frames of the north dock ore bridges have been computed in Figs. 75, 76, and 77. Since the field tests at Gary bridge No. 9 checked closely with the design sheet trolley loads for that bridge, the design sheet trolley loads for the north dock structures were used in the calculations of the above figures.

The ore load carried by the bucket represents roughly about 2 ksi of unit stress in the hanger or in the diagonal. A round trip of the trolley would consist of one trip out with loaded bucket, producing a maximum stress in the hanger and diagonal, and one return trip with empty bucket, producing a unit stress in these members about 2 ksi below the maximum. For this study a round trip has been assumed to give 1 cycle of maximum stress in the hanger and in the diagonal.

For purposes of study these failures have been plotted on an S–N diagram in Fig. 78 and compared with the following:

1. An S–N curve, Study A, obtained by plotting the results of fatigue tests on solid structural plates and I beams (i.e., without holes) obtained by Prof. W. M. Wilson and reported by him in Bulletin 302 of the University of Illinois Engineering Experiment Station. This curve may be taken as the upper limit of fatigue strength for structural steel of this grade, which has been in common use during the past 20 years.
2. The S–N curve, Study 1, was obtained by plotting the results of fatigue tests on single lap joints using bolts in full bearing and no clamping, reported by Wyly and Carter.[7a] In the opinion of the authors of this ore bridge report, the Study 1 curve may be taken as the lower limit of fatigue strength of riveted members where there are no scratches or initial cracks, etc., in the holes, and where the steel has a yield point of about 32 ksi.

It is noteworthy that the computed positions of the failures of the north dock cross frame members fall close to the lower S–N diagram, Study 1. It is not suggested that these computed values of either stress or number of cycles are necessarily highly accurate

for the north dock bridges. The weights assumed for the loaded trolley may be in error. The assumed impact of 25 percent may be in error. The actual number of round trips of the trolley is not an exactly known quantity. Nevertheless, it is believed that the information is closely and substantially correct and that the estimated position of these failures on the S–N diagram shown illustrates the relations between the factors controlling the fatigue strength of the members. This thesis will be developed and examined below.

The failures in the main truss members were also studied in the same way, and the results are plotted in Fig. 79. Most of these members were subjcted to reversal of stress during each round trip of the trolley. The effect of this reversal, as shown by both idealized diagrams[10] and actual plotting of tests results,[11] is to reduce the fatigue strength and the endurance limit. Consideration of this effect will result in a still closer agreement of these truss member failures with the Study 1 curve.

To study the effect of range of stress upon the endurance limit, Fig. 80 was drawn. In this graph both the minimum and the maximum stress occurring as the trolley makes a round trip across the bridge, one way loaded, the other unloaded, are plotted. It is seen that the range of stress for the members which have failed in fatigue is remarkably constant, being about 13.4 ksi for most of the members but also being as low as about 8.4 for several. It is noteworthy that this range holds constant even when the minimum stress runs well into the compression zone.

SUMMARY OF FACTS YIELDED BY THE SURVEY OF FAILURES

The above facts obtained in the survey of the fatigue failures in the ore bridges of the corporation are very valuable in the attempt to understand the cause of these failures. Any theory advanced must be consistent with these facts. They may be briefly summarized:

1. The failures occur only in members having a range of stress known to produce fatigue failures, i.e., zero to tension or compression to tension.
2. The unit stresses to which the failing members have been subjected are not high.
3. The crack locations occur practically always at the sides of rivet holes:
   a. In sub-punched and reamed work: at the end holes in the connections of members, gussets, or splice bars. Crack do not occur in the intermediate holes of the connections or in the top flanges of tension chords.
   b. In full punched work: at the bottom flange holes where intermediate lacing bars are connected, as well as at the end holes in stay or batten plates.
4. Where visual inspection of failure cracks has been possible by the authors, the trajectory of the cracks has been observed to coincide with the path of the line of principal tensile stress, computed on an elastic basis, which would result from rivet bearing on the material in the hole.
5. When the results of careful stress analysis and of check of total loading cycles for the members which have failed in service are plotted on S–N coordinates, they are found to cluster closely to the S–N Study 1 obtained by Wyly and Carter by fatigue testing of single lap joints which had full bearing and no clamping in the connections.
6. When the above results are plotted on a diagram showing range of stress, it is found that the range is constant whether the value of the maximum stress be 5 ksi in tension or 17 ksi in tension.
7. It thus appears that Figs. 78, 79, and 80 furnish a reliable index to the fatigue strength of structural members having riveted end connections. It does not

seem to the authors that such members should be expected to carry greater stresses in repeated loading than is shown by these graphs and that the stresses used in designing should be still lower to provide some safety factor.

INTERPRETATION OF DATA COLLECTED ON FATIGUE FAILURES IN ORE BRIDGES

Cause of Fatigue Failure in Structural Members

The pattern of fatigue failures in structural members observed in the above study of the ore bridges of the United States Steel Corporation is a duplicate of that observed in the investigation of fatigue failures in the floorbeam hangers of railway bridges which has been conducted at the Purdue University Enginering Experiment Station for the Association of American Railroads, starting in 1947, and continuing to 1954. This study has consisted of fact-finding surveys of failures in the field, field investigations of static and dynamic stresses in railway bridges under service conditions, and extensive static and fatigue laboratory tests of structural components, and has been reported in References 1 to 9 incl., listed at the end of this report. A summary of the work to 1953 is given in Reference 8. In attempting to interpret the information on ore bridge failures discussed above, it may be helpful to refer to some of the studies made in this AAR project.

The effect of a smooth round hole near the middle of a plate on the stress and strain concentration for stresses within the elastic limit is well known. When the stresses at the sides of the hole exceed the elastic limit in a structural steel plate, the stress concentration changes little if at all, but the strain concentration rises rapidly.[8a] Subsequently, after some cycles of unloading and reloading, or after a period of rest, the steel will be found to be elastic to the point of previous plastic flow,[8b] so that when eventually a crack starts, its location both in point of initiation and in travel as it grows, will be found to coincide exactly with that line of principal stress which gives a maximum value in tension at the side of the hole,[8c] this principal stress being computed on an elastic basis.

The stress and strain concentrations for stresses within the elastic limit due to the presence of the hole are materially increased by:

1. Locating the hole near the edge of the plate, i.e., using a small edge distance.[5a]
2. Adding bending to the axial stress on the plate.[5b]

The effect on the stress at the sides of a hole near the middle of a plate for stresses within the elastic limit, of the bearing of a rivet or bolt at the top of the hole is to increase the stress and strain concentration.[8d] This concentration is proportional to average bearing stress. For the common case of a 1-in rivet it is about 1.3 times the average bearing stress of the rivet on the plate, or about 1.3 times $27 = 35$ ksi. Also it is very important to note that the line of principal tensile stress (maximum), and consequently the path of the fatigue crack, now begins, not at the transverse axis of the rivet hole, but above it toward the side of the hole on which the rivet bears and about one-sixth of the rivet diameter in distance,[8e] and is no longer a straight line, but a curve.

The stress and strain concentration for stresses within the elastic limit due to the rivet bearing are materially increased by:

1. Locating the hole near the edge of the plate, i.e., using a small edge distance.[6c]
2. Adding bending to the axial stress in the plate.[6c]

The rivets at the extreme end of a splice, i.e., at the end of the splice or gusset plate, or at the ends of a member, carry most of the load at design stresses and the interior rivets carry little.[8f]

The effect of slip at the edge of the gusset or splice plate with respect to the main material is to cause the rivet to come to bear upon the edge of the plate only, and to produce a very high, very local stress and strain concentration at the sides of the hole at the contract surface.[8g, 6d]

The above facts explain why fatigue failure in a riveted joint almost invariably occurs at the end rivets in the connection and why the fatigue strength of a double lap joint is, in general, greater than that of a single lap joint. A further factor of great influence also enters—the clamping force of the rivet. A high clamping force produces these results:

1. Slip does not occur or is greatly reduced in magnitude.
2. The eccentric bearing effect just discussed above is greatly mitigated and the severe stress and strain concentrations shown in Fig. 12 of Reference[8] are much reduced[8h] or do not occur at all.[5e]

Hence it seems probable that structural fatigue cracks do occur only when the end rivets in the connection have a low clamping force. This is probably the main reason why the number of structural members that do not fail are greater than the number that do fail.

Very good evidence that the above line of reasoning is correct is the exact location and path of the fatigue crack at the rivet hole. Where it begins about one-sixth of a diameter above the center line of the hole normal to the line of stress in the member, and off center on the rivet bearing side, as illustrated in Reference 8e, Fig. 11, we may be sure that the maximum principal stress is caused by rivet bearing. Another photograph of this type of failure is given in Reference 8i. In a centrally loaded plate with an open central hole and no rivet in place, the fatigue crack normally starts at the side of the hole and proceeds outward on a radial or diametral line.[8c]

Manufacturing and construction operations which may reduce the fatigue strength are:

1. Drifting.
2. Full punching of holes.

In Reference 8, Fig. 7A, there is shown in Study 4 the results of fatigue tests on a 4½-in by 3⅜-in steel plate in which the 2 rivet holes for connection at one end had been drifted. In this case 2 plates, each having 1-in bored holes, were placed in contact, with the holes off center with respect to each other an amount of 1/32 in. A polished 1-in drift pin held normal to the plates was forced through the holes, thus elongating them in the direction of the stress but not in a transverse direction. The connection consisted of two smooth bolts in full bearing and no clamping. One plate failed in fatigue after 70,000 cycles of axial stress varying from 1 ksi to 14 ksi on the gross section, or 1 ksi to 18 ksi on the net section. The second plate tested in the same manner failed after about the same number of cycles. This result illustrates the effect of initial infinitesimal cracks at the sides of the hole in building up stress and strain concentrations and in reducing fatigue strength. It is thus clear that drifting should not be used in the holes of members which are subjected to fatigue loading.

The full-size punching of holes in tension members subject to fatigue undoubtedly has an effect upon fatigue strength similar to that of drifting. It is well known that this

operation sets up very fine cracks at the edges of the hole. The analogy of the crack as a greatly elongated ellipse, with a correspondingly magnified strain concentration factor, is useful in visualizing the effect of the crack in reducing fatigue strength. Given punched holes and even the reduced rivet bearing operating at the end of the stay plate as the member stretches under load, it is not difficult to explain lowered fatigue strength. While not usually considered as carrying stress, it is plain that the stay plate will have to stretch as the main material stretches under load, and this means that a certain amount of rivet bearing on the main material will occur in the end rivets through the stay plate. Also, when lacing acts, a certain amount of rivet bearing on the main material will occur. The occurrence of a considerable number of fatigue failures through these end rivets in the stay plates, and also through the lacing connections along the member, while none have occurred through the rivet holes in the top flanges of the same top chord channels, is good evidence of the weakening effect of this full punching of holes.

The question of any possible weakness or flaw in the steel of the north dock bridges was referred to the American Bridge Division engineers. Both Mr. Beard and Mr. Greene reported that no reason could be found to suspect any such weakness. A typical test report furnished by Mr. Greene showed:

Yield point	37,230 psi
Ultimate	62,480 psi
Elongation in 8 in	29 percent
180 deg bend	$D = \frac{1}{2} T$ is O.K.

Above information was furnished in a letter of August 7, 1953, from Mr. Pierce to Mr. Davidson.

A summary of conclusions regarding the probable causes of fatigue failure in the truss and cross frame members of the ore bridges may be made as follows:

1. The slip of component parts at the end rivets resulting from loss or absence of high clamping force in the rivets, allowing these rivets to come to full bearing upon the metal at the holes (as is assumed in design) is sufficient action to cause fatigue failures to occur at stresses and at the number of cycles indicated by the S–N graph Study 1 in Fig. 78, and at the range of stress indicated by Fig. 80 of this report. (Usually the bearing in the end rivets will be several times the assumed design load).
2. If the clamping force in the rivets is high, slip probably will not occur, and fatigue failure will not occur. If clamping force is not high but still substantial, the slip will probably be smaller, less bearing may be expected, and fatigue cracks will start and propagate more slowly.
3. Drifting of holes during manufacture and construction will greatly reduce fatigue strength, much below the Study 1 graph noted above. This applies to any hole in the stress carrying material, whether main section or splicing components. The seeemingly innocent operation of driving drift pins through the assembly holes for stay plates or lacing on the main material can easily cause a failure after 100,000 or fewer cycles of maximum stress.
4. There is every reason to believe that full-size punching of any hole in the stress-carrying material, whether main section or splicing components, can produce a marked lowering of fatigue strength, particularly when the rivets in the holes exert bearing. The punching of full-size holes in the flanges of top chords for connections to stay plates and lacing may easily be the cause of a lot of fatigue failures in these members. (See Figs. 72 and 73).

5. The present allowable edge distances for rivets in rolled shapes are undoubtedly too low. In Fig. 69 a crack is shown in the flange of the main channel at the end of the splice bar. The gage at this flange is 2½ in, the edge distance 1.21 in, and the ratio of edge distance to rivet diameter is 1.38. This leaves a clear width of metal at the hole of 0.91 in. With some bending stress added to axial stress, the stress and strain concentration at the sides of this hole could be quite large.[5a, 5c] The allowable edge distance by present specifications is 1¼ times the rivet diameter for a channel or an I-beam flange.
6. The weakness of the rolled channel flanges of the top chord in fatigue strength even where wider edge distances are used, suggests that other factors may be involved. These may be stated as follows:
   a. It is difficult to get full centered heads and tight rivets in the sloping flanges of the structural channels. This is particularly true in field connections. With loss of clamping force the bearing stress at the end of a connection will go up and the fatigue strength will go down.
   b. It is possible that the punching of the beveled flange produces a very severe distortion on one side of the hole, with consequent opening of hair cracks which assembly reaming may not remove.
7. As a general statement, any circumstance which will produce a high local stress and strain concentration in members subject to fatigue loading will contribute to or directly cause lowered fatigue strength. A fatigue loading may be considered to be a cycle varying from minimum tension (or maximum compression) to maximum tension repeated many times.

A working hypothesis to explain the fatigue failures in railway bridges and a proposed remedy were offered by one of the authors in 1947 after considering the facts available similar to those discussed above.[2a] Since these statements apply equally well to the ore bridge fatigue failures they will be repeated here.

Working Hypothesis to Explain the Fatigue Failures in Hangers

"It is assumed that the index to the fatigue strength of a structural member is given by the magnitude of the tensile stress concentrations, computed on the elastic basis, and the total tensile strain concentrations, to which the member is repeatedly subjected. The principal source of high stress and strain concentrations which result in the low fatigue strength of the hangers is the bearing of the rivets nearest the edge of the gussets in the holes at the failure section, probably acting in most cases with rivets which have lost or never had clamping force."

Proposed Remedy for Fatigue Failures

"In the light of the above reasoning the remedy must lie in the elimination of bearing in the rivets at the edge of the gussets and the securing of high clamping force at these holes.

"The natural solution for fatigue failures in riveted joints is the replacement of the rivets by non-bearing high-strength high-clamping bolts which will have ample initial clearance in the hole and hence will not bear on the plates, and to provide these bolts with a high clamping force to prevent slip and to provide an initial compression stress and strain at the sides of the holes."

MECHANISM OF FATIGUE FAILURE

A good exposition of one of the generally accepted explanations of the mechanism of fatigue failure is given by Gensamer.[12]

"Ultimate failure in fatigue results from the propagation of a crack caused in the first place by repeated minute amounts of plastic deformation. Plastic deformation requires a certain shear stress. Stress raisers like notches and fillets provide locally high shear stresses, so that nominally low stresses, frequently applied, may cause a crack to form at the point of greatest shear stress, generally at the base of the notch. This crack spreads as the repeated loading cold works and weakens the metal at the base of the advancing crack, until the remaining area is so small and the stress concentration factor so large (because of the deepening crack) that failure finally occurs as a crack propagating all the way across during a single application of the load. The crack nearly always follows such a direction as to be everywhere perpendicular to the greatest normal stress, both in the stage of slow development and during its final rapid propagation. In this process, then, stress raisers play the same role they do in so-called static failures; but the repetitive deformation in fatigue has lowered the normal stress required for cohesive failure and converted a ductile material capable of deforming in spite of the stress raisers, to a material which behaves in a brittle fashion in the presence of these same stress raisers."

SIGNIFICANT FACTS

The ore bridge investigation for the American Bridge Division and the floorbeam hanger investigation for the Association of American Railroads have developed the following facts which are thought to have significance regarding the explanation of the failure of structural members in fatigue.

1. In a riveted connection failure cracks always originate in the member at the end holes in the gussets and in the gussets at the end holes in the member.
2. In the riveted connections, the fatigue cracks which have been observed in this field coincide in locations, both at initiation and in propagation, with the trajectory of the maximum (tensile) principal stress, computed on the elastic basis, due in whole or in large part to rivet bearing.
3. Fatigue failures occur in many cases through the full punched holes in the angles or flanges of chord or web members where lacing bars on the ends of batten plates are riveted on. It is well known that full punching sets up many fine hair cracks in the edge of the hole.
4. Fatigue cracks appear very early at the sides of holes in plates which have been elongated by polished drift pins. The explanation is undoubtedly similar to that of the full punched holes.[8m]
5. The fatigue strength of plates having holes which have been elongated in all directions by polished drift pins is high, no failures having been found after 5,000,000 cycles of stress. The explanation is undoubtedly twofold:[8n]
   a. The metal is stretched tangentially at the same time that it is compressed radially—a state of stress which produces ductile shear flow and not a tendency towards brittleness.
   b. Upon removal of the pin after enlarging of the hole, the elastic shrinking of the metal surrounding the hole sets up tangential compression at the sides of the hole which acts to prevent cracks opening up.
6. The stress gradient accompanying the stress concentrations where a pin or rivet bears on the face of a contact plate after slip in a single lap joint, or where the washer bears on the plate under the edge of the bolt circle in a high-strength bolt head or nut, is very steep.
7. The state of stress at the side of the hole is biaxial or triaxial, and tends toward a brittle condition.

8. The stress concentration factor at the side of a hole is of about the same magnitude after the metal has passed into the yield range that it was before.
9. Bearing stress is reduced by high clamping and the very high local stress concentration at the side of the hole due to a rivet bearing on the edge of the metal at the face of the plate in a single lap joint when slip occurs is also greatly minimized and reduced by high clamping.

Part 4

Recommendations For Prevention of Fatigue Failures In Ore Bridges

GENERAL STATEMENT

Fatigue Strength of the Material

Prof. W. M. Wilson and others have demonstrated that riveted structural joints fabricated with silicon steel do not perform well in general under fatigue loading. This fact, together with the higher unit stresses allowed with its use, may be expected to aggravate any tendency towards fatigue failure as a result of high local stress and strain concentrations.

In general, however, the problem is not that of the main material. Under the present AREA specifications for design of bridges, and the specifications of the American Bridge Division, under which the South Works bridges were designed, computation of the design load for members subjected to reversal of stress is made as follows: "Determine the maximum stress of one sign, and the maximum stress of the opposite sign and increase each by 50 percent of the smaller. Proportion the member so that it will be capable of resisting either stress so increased. The connections shall be proportioned for the sum of the maximum stresses."

Since no failures of the main material, except at the connections, have been reported, it may be assumed that the procedure is at least satisfactory from the standpoint of safety.

It follows directly from the nature of the causes of fatigue failures that the introduction of any severe stress or strain raiser into the main material is likely to produce fatigue. Examples of how such stress and strain raisers may be introduced are:

1. Any welding of the main material, even for a small connection to a small conduit.
2. Any burning of the main material.
3. Any sharp or re-entrant notches in the main material; the coping of a beam or other re-entrant cuts are examples.
4. Rivet holes without local distortion of the material, i.e., as form factors.
5. Hair or microscopic cracks induced in the sides of rivet holes by:
   a. Full punching.
   b. Drifting.
6. Bearing of the rivet on the material at the sides of the rivet hole:
   a. Uniform bearing.
   b. Eccentric bearing, i.e., after slip, when the rivet bears on the edge of the rivet hole at the contact face of the plate.

Fatigue Strength of the Main Material at the Connections

There are two requirements for the design of connections so that they will not cause fatigue failures in the main material:

1. Adopt connections that will not produce high stress and strain concentrations in the main material.
2. Proportion the connection on the basis of S–N diagrams experimentally derived for the type of connection and for the main material used.

The natural solution of the first requirement is the substitution of the high-strength bolt for the rivet and the installation of it in a satisfactory manner in holes which have not been damaged.

To obtain the S–N graphs noted under Item 2 above, it is necessary that fatigue tests be run, studying one variable at a time, over a wide range of variables. This is largely a future assignment. Where more than one variable is involved, the results are generally difficult or impossible to interpret.

At the present state of engineering knowledge on this subject, it would be wise to adopt such measures as may be expected to eliminate the known causes of fatigue failures, but not to change radically the specifications for computing design stress. Where live-load reversal is involved, the AREA specifications for the design of bridges require the design stress for the connections to be taken as the sum of the maximum tension stress and the maximum compression stress. The authors see no reason to change this practice at this time.

The High-Strength Bolt; Fatigue Tests

In order to test the soundness of the reasoning leading to the substitution of the high-strength bolt for the hot-driven rivet, several series of fatigue tests were run at Purdue University where a single variable at a time was studied. The spread of results from fatigue tests is frequently noted. It is the belief of the authors, however, based upon the results of these tests, that where only one factor is allowed to vary, all others being held constant, that remarkably small spread may be found.

The results of these tests are shown in Figs. 7A and 8 of Reference 8. In all series the rate of loading was 17 cps and all high-strength bolts used were torqued into the yield strength range. In all series, except the beam test, specimens were cut from the same plate; the specimens were the same size, i.e., 4½ by ⅜ in, with edges sheared; each end connection was through two bored holes of 1-in diameter; and the testing set up and procedure was the same. For the specimens tested to establish the Study 1 S–N curve shown in Figs. 7A and 8 above mentioned, no clamping was used, and load was delivered to the specimen plate by full bearing of bolts turned to a push fit in the holes. For the specimens tested to establish the Study 2 S–N curve shown in the same figures, all bearing was eliminated and high clamping was secured by use of high-strength bolts having 1 in diameter at the threads and ⅞ in diameter at the shank. The effect of elimination of the high bearing stress at the bolt holes and the introduction of high clamping was to raise the endurance limit of the connection from about 12.4 ksi to 18.7 ksi on the gross area, or from about 16 ksi to about 24 ksi on the net area.[8j]

This increase in fatigue strength was accompanied by and limited by a different type of fatigue crack not through the holes but in the main plate under the washer at the edge of the bolt head or nut where tension at the plate surface due to clamping would be large. Reference 8 shows this type of failure by photograph[8k] and explains it by measurements in plastic models by polarized light.[8l] Fig. 14 shows the paths of the

principal tension stresses at the surface of the plate under the edge of the washer when pressure is applied to the washer. Figs. 13 (d) and 15 (b) show the high magnitude of these tensile stresses and the very sharp stress gradients involved. In the tests for Study 2 the washers used were thinner than those recommended later by the Research Council for Riveted and Bolted Structural Joints, and were undoubtedly too thin, resulting in higher bearing stress at the point of failure than was necessary or desirable. For the single test 2A all circumstances were the same as in Study 2 except that the clamping force, while ample to prevent slip, was less than for the others, resulting in a smaller stress concentration under the washer. The 17 percent increase in fatigue strength may be attributed directly to this smaller stress concentration. In no case was any slip greater than about 0.001 in.

To further demonstrate the beneficial effect of eliminating rivet bearing and adding high clamping, and also to demonstrate that the same factors control the fatigue strength both of beams with cover plates and of single lap joints, the test of a 10-in wide flange beam with partial length cover plates connected by high tensile bolts was made. (See Fig. 7A Study 3 and Fig. 10, Reference 8). After stressing to an extreme fiber unit stress of 21.5 ksi on the gross section, or 28.6 ksi on the net section, at the end of the cover plates for 5,000,000 cycles, no slip had occurred and no failure had occurred, and the test was stopped. In this test the washers used conformed to the present specifications recommended by the Research Council on Riveted and Bolted Structural Joints. It seems highly probable that considerably greater stresses could have been used on this beam with the bolted cover plates without incurring failure. The above tests, Study 2A and the beam test, demonstrate the necessity for proper design of the washers. A project to study this subject, sponsored by the Research Council on Riveted and Bolted Structural Joints, is being conducted at Purdue University.

Static Test of Large Joints Connected By High-Strength Bolts

A static test of two large structural joints connected in whole or in part by high-strength bolts was recently completed at the Purdue University Experiment Station[9] which showed favorable performance. The fully bolted joint showed very good load carrying properties with less slip at working loads than a riveted joint. The second joint, riveted throughout except for the two rows of holes at the edges of the gussets, also showed no major slip at working loads.

SPECIFIC STEPS

RECOMMENDATIONS FOR DESIGN AND MANUFACTURE OF NEW ORE BRIDGES

Design

1. Members to be included: Any member subjected to a range of stress from minimum to maximum and especially a resultant tensile stress due to dead load plus live load plus impact greater than about 5 ksi is included in the following recommendations.

2. For stringer hangers and main truss members the secondary bending stress should be computed and treated as an axial stress.

3. Proportioning of members: Use Sec. A, Art. 28—Reversal of Stress, of the 1954 Edition of AREA Specifications for Steel Railway Bridges.

4. Eliminate the use of standard structural channels or standard I beams with sloping flanges. Use ship channels and Carnegie or wide flange beams having wide flanges parallel or nearly parallel.

5. Use high-strength bolts in all holes in the connection.

6. Design of high-tensile bolted connections should be based on an S–N curve for the connections as soon as available. Substitution of a bolt of same nominal diameter as the rivet is not very scientific and should be discontinued as soon as experimental developments justify.

7. Carburized washers should probably be thicker and wider than now specified. In no case should they be thinner or less wide. This should be checked experimentally as soon as possible by fatigue tests.

8. Edge distances, measured from center of hole to edge of plate should not be less than the following in stress carrying material:

	Rolled Edge	*Guided Flame-Cut Edge*
Measured in line of stress	2 diameters	2¼ diameters
Measured normal to line of stress	2 diameters	2¼ diameters

The above should be checked by fatigue tests as soon as possible.

9. Use solid or perforated plates instead of lacing and stay plates.

10. If rivets are to be used instead of high-strength bolts, the allowable range of unit stresses on the gross area of the member should not exceed 60 percent of the endurance limit range shown by the members whose failures are plotted in Figs. 78, 79, and 80 of this report. In other words the above range of stress, from minimum to maximum, dead load plus live load plus impact, should not exceed about 8 ksi. If rivets are to be used they should be of ASTM 141 Steel. In no case should alloy steel rivets be used and in no case should cold driven rivets be permitted.

Manufacture and Construction

1. Do not use low-alloy high-strength steel ASTM A–8, A–94, or A–242, with riveted connections.

2. Do not use sheared plates for main members or on gussets or splice plates carrying high stress. Use no hand-burned edges. Use the machine guided flame-cut and flame-annealed process. This should be checked by fatigue tests as soon as possible. Avoid re-entrant or rough cuts or notches at beginning and end of cut.

3. Use no weld or burning of any place on the member or connections.

4. Prohibit full-size punched holes altogether, even for rivets connecting lacing and batten plates to member. Sub-punch and ream or drill. Use sharp reamers and get smooth holes.

5. The operation of drifting should be greatly curtailed and vigorously controlled. Heavy drifting commonly used to pull members into line, to enlarge holes for better fit, and in some cases to induce stress into the members, should be prohibited altogether. Light drifting where the weight of the member is held by a rig, and where enlargement or distortion of the holes does not occur, should be permitted only in holes near the middle of the connection. The above recommendation is made on the basis of two assumptions:

a. That high-strength bolts are to be used in all holes, that they will have a high clamping force, and that they will not come to bear on the main material.

b. That the reduced fatigue strength accompanying or resulting from drifting is due to rivet or bolt stress in the hole after the drifting has occurred and to damage by drifting.

The safety of this practice should be checked by fatigue tests as soon as possible. It is highly probable that drifting greatly reduces the fatigue strength of the metal at the sides of the hole. This probably will be offset somewhat by two facts:

a. The stress in the main material is reduced after the two lines of bolts at the end of the gussets have been passed.
b. High clamping will increase the fatigue strength through the lightly drifted holes.

No drifting should be permitted under any circumstances in the two lines of holes at the edges of the gussets or splice plates, or in the two lines of holes at the ends of the main material inside the joint or splice. No drifting should be permitted in shop or field operations in holes for rivets connecting lacing or batten plates to main material.

6. Assembly of high strength bolts:

a. Work from center of plate towards the outside in torquing up bolts to avoid wrinkles.
b. Torque bolts into the yield stress range but well below the breaking stress. It is suggested that the recommendations made by the AAR Research Center, which indicate that one full turn of the nut after the nut is finger tight, will probably be found very satisfactory.
c. Thirty minutes or more after bolts have been first torqued up, go over all bolts and retighten them.
d. Do not unscrew any nut on any bolt unless both are to be removed and thrown away. If high-strength bolts are to be used as fitting up bolts, they should not be loosened, but the same bolts should be further tightened as recommended in (b) above. Do not use any bolt or nut twice.
e. Provide a satisfactory direct field check of actual clamping force in kips put into bolts. Measurement of strains or elongation of the bolts are misleading and unsatisfactory for this purpose.

The above is in addition to the latest specifications of the Research Council for Riveted and Bolted Structural Joints. Much more information on the strength and clamping force of high-strength bolts as installed in the shop or field is needed. The above recommendations should be revised as such information, when obtained, indicates to be desirable.

RECOMMENDATION FOR PROTECTION OF EXISTING ORE BRIDGES

The protection against fatigue failure of existing ore bridges involves two problems:

1. The elimination of high local stress and strain raisers. For the most part this means the replacement of rivets at the ends of the plates with high-strength bolts.
2. The estimate of the fatigue strength of the main material at the connections after Item 1 has been taken care of.

Since it is the end rivets in the connection (i.e., those at the edge of the gusset or splice plate or at the end of the main material) which are over loaded and which come into bearing, it would seem sufficient to replace these rivets by high-strength bolts.

Probably the most critical phase of this operation is the removal of the existing rivets without damage, at the rivet holes, to the main material and in the gussets or

splice plates. The use of a bridgeman's "cutter", whereby the rivet head is party cut off and partly lifted off the main material, probably results in straining the material at the sides of the holes in about the same manner, and perhaps to about the same degree, as would drifting. Also, the edges of the material at the holes is liable to be gouged or scored, which would be bad. The drilling out of rivets in the field is probably prohibitive economically. If the rivet could be blown out by a torch in such away that the main material is not burned or damaged, the problem might be solved, but the danger of damage to the main material is so great that it is doubtful if this should even be considered. Perhaps there could be made a tool consisting of a pair of hydraulically operated cutters, working against each other on the pliers principle, and tending to lift as well as cut the rivet head. In any event, it is essential that the main material be not damaged at the edge of the hole when the rivet is removed.

While the static test of the large joint, noted above, in which the rivets in the end holes of the connection had been replaced by high-strength bolts, showed no major slip at working loads, and is thus evidence favorable to this operation, confirmatory fatigue tests have still to be run. This should be done before the matter is considered settled.

The authors do not consider it to be feasible or practicable to successfully design or to rate a riveted connection for fatigue loading, since fatigue tests of such joints show a very wide spread. The authors believe this to be due to the fact that the actual value of the clamping force acting in the rivets, and the actual bearing of the rivets in the material at the holes, two factors which are inversely related to each other in general, are unknown, and they do not believe it possible to accurately predict what they will be in a given connection. The fact that while many riveted connections have failed in the north dock bridges, many more, subjected to the same loadings, have not failed, is good evidence in support of this statement. The recent studies at Northwestern University by McCammon and Yoshima, for the Research Council for Riveted and Bolted Structural Joints, shows that the clamping force in the individual rivets of a joint may be expected to vary from the yield point to a low stress. Also, the maximum clamping force of the rivet cannot exceed the tensile yield point strength of the rivet, which is about one-third of the tensile yield strength of the high-strength bolt, so that the tendency of the riveted joint to slip at the end rivets is necessarily greater than that of a bolted joint. This fact will always lower the fatigue strength of the riveted joint below that of the bolted joint.

There are thus two alternate methods of attempting to protect the existing riveted ore bridge connections:

1. To replace all rivets in the connection by high-strength bolts.
2. To try out the idea of replacing the rivets in the holes at each end of the connection.

For the cross frame members and the main truss diagonals it is recommended that the second method be given a good trial. This includes the cross frame gussets. The matter of the main truss top chords presents a difficult problem. Several of the failure cracks reported have been through the webs of the channels. (See Fig. 70). These holes were sub-punched and reamed assembled. Several cracks have originated at the holes for the end rivets in a splice bar or angle used at the panel point joint to splice the flanges of the two chords together. (See Figs. 69 and 71). These holes also were marked for sub-punching and assembly reaming on the shop plans. However, the great majority of the cracks recorded in the top chords were through the rivet holes where lacing bars

were connected to the flanges or through the end rivet holes in stay plates on the lower flanges of the chords. These holes were punched full size. It is entirely possible that drifting could account for the cracks in the first two cases. The cracks through the holes for connections to lacing and stay plates, however, are so numerous that it hardly seems likely that they were all drifted, although this is possible. It seems most likely that the cracks were due to a certain amount of rivet bearing in the full-size punched holes. It is noteworthy that no cracks have been recorded in the sub-punched and reamed holes in the top flanges of these same channels where the cover plates are connected. It is probably necessary to have some rivet bearing in such holes to cause such early failure. However, lacing in tension members frequently carries an appreciable amount of shear. Also, the lacing bars at the stay plates suffer a certain amount of participation stress as the main material stretches under load. The stay plates also stretch with the main material. These circumstances all will put some stress in the rivets in question.

There is the final aggravating factor that not only do low alloy high strength steel riveted joints have about the same fatigue strength as ASTM A–7 steel joints, but that the material is normally used at a higher unit stress than ordinary structural steel. The authors doubt that this is a factor of great importance, however.

By replacing the rivets in the following locations with high-strength bolts, it should be possible to prevent cracks in the sub punched and reamed holes for the most part:

1. Rivets at the edges of gussets and splice plates in both horizontal and vertical planes.
2. Rivets connecting the top chord directly to web members.

Where the edge distance will not be made too small, the last 2 rivets at the ends of the stay plates could be removed, the holes reamed out ⅛ to ¼ in, and high-strength bolts installed. For the connections to the lacing bars a similar process seems the only choice. Unfortunately, a number of the failures through these holes occur in the middle of the member, or at least not at the stay plates. This means that all holes for lacing bar connections would have to be reamed out and high-strength bolts installed. Where the edge distance is too small to permit reaming, perhaps filleting of the edge of the present holes to a depth of about $\frac{1}{16}$ in with a sharp tool might help. This whole process is economically prohibitive.

It is doubtful that anyone can say with assurance how successful the above measures will be in protecting the silicon steel top chords against future fatigue failure.

Finally, the authors do not feel that the evidence in either the ore bridge investigation or in the floorbeam hanger investigation entitles anyone to count on greater fatigue strengths in single lap riveted joints in steel than are shown by the S–N graphs of Figs. 78 and 79 and by the fatigue stress range graphs of Fig. 80 of this report. And for designing, a safety factor should be added.

ESSENTIAL RESEARCH PROPOSED

The following problems should be studied at the earliest possible time:

1. Design of gussets: analytical and experimental work.
2. A general program of fatigue tests to determine the fatigue strength of connections, studying one variable at a time only, where the variables would be:
   a. Condition of holes, bored, drilled, punched.
   b. Drifting, polished pin and rough pin.

c. Clamping force, none, bearing, full; or full clamping force no bearing.
d. Hole diameter $\frac{15}{16}$ and $1\frac{1}{16}$ in.
e. Number of holes in single line, — 2, 4, 6, 8.

List of References

1. A Study of the Behavior of Floorbeam Hangers. Static and Dynamic Stress Measurements on the Illinois Central Railroad Bridge at Galena, Illinois, by L. T. Wyly, M. B. Scott, L. B. McCammon, C. W. Lindner. AREA Proc. v. 51, 1950, p. 51, ff.
2. Stress Distribution in Bridge Frames. Progress Report on Investigation Conducted at Purdue University Engineering Experiment Station with the assistance of AAR Research Office for the Association of American Railroads, under the direction of L. T. Wyly. AREA Proc. v. 51, 1950, p. 470, ff.
   a. p. 498–9
3. The Effect of Various Fasteners on the Fatigue Strength of a Structural Joint, by K. H. Lenzen, AREA Proc. v. 51, 1950, p. 1, ff.
4. Strain-Testing Railroad Bridges, by A.D.M. Lewis, Electronics, September 1951.
5. Stress Concentration in Built-Up Structural Members, by J. W. Carter, AREA Proc. v. 53, 1952, p. 1, ff.
   a. Fig. 12
   b. Fig. 10
   c. Fig. 13
   d. Table 1, page 23, Fig. 19
   e. Figs. 21, 26, 27
6. A Further Study of the Behavior of Floorbeam Hangers. Static Stress Measurements on the AT&SF Railway Bridge near Ponca City, Okla., by M. B. Scott and J. W. Cox. AREA Proc. v. 53, 1952, p. 35, ff.
7. Stress Distribution in Bridge Frames. Rigid Frame Analysis for Members of Variable Moment of Inertia, Directed Especially Towards Floorbeam Hanger Frames and Counterweight trusses. Analytical and Experimental Studies in five parts by L. T. Wyly, M. B. Scott, J. W. Cox, K. H. Lenzen, and W. J. Grady, Jr., of Purdue University and by E. J. Ruble of the Association of American Railroads Research Office. AREA Proc. v. 54, 1953, p. 1, ff.
   a. P. 63, 4. Fig. 23, Table 2
8. Fatigue in Riveted and Bolted Single Lap Joints, by J. W. Carter, K. H. Lenzen, and L. T. Wyly, ASCE Separate 469, August 1954.
   a. Figs. 2, 3, and 4
   b. Fig. 2
   c. Fig. 5
   d. Fig. 6
   e. Fig. 11
   f. Fig. 9
   g. Fig. 7B(b), also Fig. 12.
   h. Fig. 13 and Fig. 15
   i. Fig. 1a
   j. Fig. 7A
   k. Fig. 1(c)
   l. Figs. 13, 14, 15
   m. Fig. 7A, p. 24. See study 4
   n. Fig. 7A, p. 24. See study 5

9. Comparative Test of a Structural Joint Connected with High-Strength Bolts and a Structural Joint Connected with Rivets and High-Strength Bolts, by J. W. Carter, J. C. McCalley, L. T. Wyly. AREA Proc. v. 56, 1955, p. 217, ff.

10. Resistance of Materials by F. B. Seely, Third Edition, John Wiley & Sons, New York, 1947. p. 298, Fig. 303.

11. Prevention of the Failure of Metals Under Repeated Stress, by Battelle Memorial Institute, John Wiley & Sons, Inc., New York, 1941, p. 131, Fig. 110.

12. Strength of Materials Under Combined Stress, by Maxwell Gensamer. American Society for Metals, 1941, p. 26.

TABLE 1

LIVE LOAD COMPARISON IN NORTH TRUSS

GARY ORE BRIDGE NO. 9

TOTAL LOADS IN TRUSS MEMBERS

Member	Section	Stress Value from Stress Sheet LL + Imp. *	Computed Stress LL Only*	Experimentally Measured Stresses Static Run Values	Static Ave	Dynamic Run Values	Dynamic Ave	Impact ** %
				T				
$L_{17}M_{18}$	DC-1	-130^k	-113.7	-124.9	-124.9	-146.7	-146.7	18
$M_{18}U_{17}$	DC-2 DC-3 DC-4	+125^k	+107.9	+120.9 +118.8	+119.8	+145.0 +132.2 +149.0	+142.1	18
$L_{18}M_{19}$	DC-5	-126^k	-110	-121.2	-121.2	-134.0	-134.0	11
$M_{19}U_{18}$	DC-6 DC-7 DC-8	+136^k	+118.8	+111.0 +106.2	+108.6	+143.1 +157.2 +147.0	+149.1	37
$M_{15}L_{16}$	DM-1	+126^k -132^k				-115.0	-115.0	
$M_{15}U_{16}$	DM-2 DM-3 DM-4	-120^k +126^k				+116.0 +130.0 +118.0	+121.3	
$L_{17}L_{18}$	IC-1	-608^k	-498 -439	-389.0	-389.0			
$M_{15}U_{16}$	DM-4	(Skewed)				+125.0	+125.0	

Notes: * Trolley in position to produce maximum live load stress, except IC-1.

** Impact taken $100\,\frac{D-S}{S}$ in percent

where D = average measured dynamic stress
S = average measured static stress

TABLE 2

SUMMARY OF MEASURED AND DESIGN LOADS
FOR
ORE BRIDGE NO. 2

EDGAR THOMSON STEEL WORKS

		TOTAL LOAD IN TRUSS MEMBERS (SPAN SQUARE)					
		Stress Sheet Loads (in kips)			Measured Loads (in kips)		
Member	Section	L	I	Total	Static	Dynamic	Remarks
	DM-1						
U_5L_6		+106	+27	+133	+113.5	+118.0	
		- 9	- 2	- 11	- 5.6	- 6.3	
	DM-2				+116.3	+117.6	
					- 4.0	- 4.7	
U_6L_7	DM-3	+ 79	+20	+ 99	+ 32.2	+ 35.7	Main Diagonal
					- 27.9	-35.8	Counter Diagonal
L_6U_7	DM-4	+ 37	+19	+ 56	- 46.6*	- 43.5*	*Ave. of skewed values.
					- 9.4*	+ 8.7*	
U_6L_6	VM-1	- 86	-22	-108	- 68.**	- 81.9	**Ave of skewed values is 82.6
		+ 7	+ 2	+ 9	+ 11.	+ 12.3	
	DT-1				- 16.5	- 27.1	
L_4U_5	DT-2	+ 74	+19	+ 93	- 83.1	- 84.3	
		- 63	-16	- 79	+ 60.9		
U_4U_5	UT-1	+203	+51	+254	+135.5	+112.5***	***Probably this value is lower than static due to trolley Positions.
		- 29	- 7	- 36	- 32.5	- 35.4	
U_4U_5	UT-2				+ 16.8	+ 50.2	
					- 11.7	- 10.9	
U_5U_6	UM-1	+148	+37	+185	+163.1	+ 92.4***	*** See above.
		-149	-37	-186	-171.2	-194.5	
U_5U_6	UM-F	+148	+37	+185	+142.0	+ 78.2***	*** See Above.
		-149	-37	-186	-154.1	-178.5	
U_6U_7	UM-2	+116	+29	+145	+131.5	+ 87.6***	*** See Above.
		-167	-42	-209	-138.5	-153.8	

TABLE 3. General Data, South Works Ore Bridges

Dock	Bridge No.	Built	Total Length	Trusses Type	Trusses Silicon Steel Chords	Rated Bucket Ore Load	Nominal Wt. Loaded Trolley	Reported by 1954 Trusses	Reported by 1954 Frames	Millions of tons Carried	Thousands of Trolley Trips
						tons	kips				
North	1	1927	518'-9	Warren		18	240	1	21	22.57	1562
	2	1937	525'-6	K	Point 4	15, 1937-40 22 1/2, 1941-54	300	21	57+	20.41	1200
	3	1941	524'-4	K	do	22 1/2	380	12	1	17.63	976
	4	1941	524'-4	K	Point 21	22½	380	3	1	8.71	426
South	1	1944	479'-10	K		22			1		
	2	1943	479'-10	K		22					

Notes: 1. Bridges 3 and 4 of North Dock are identical. Bridge 2 is similar.

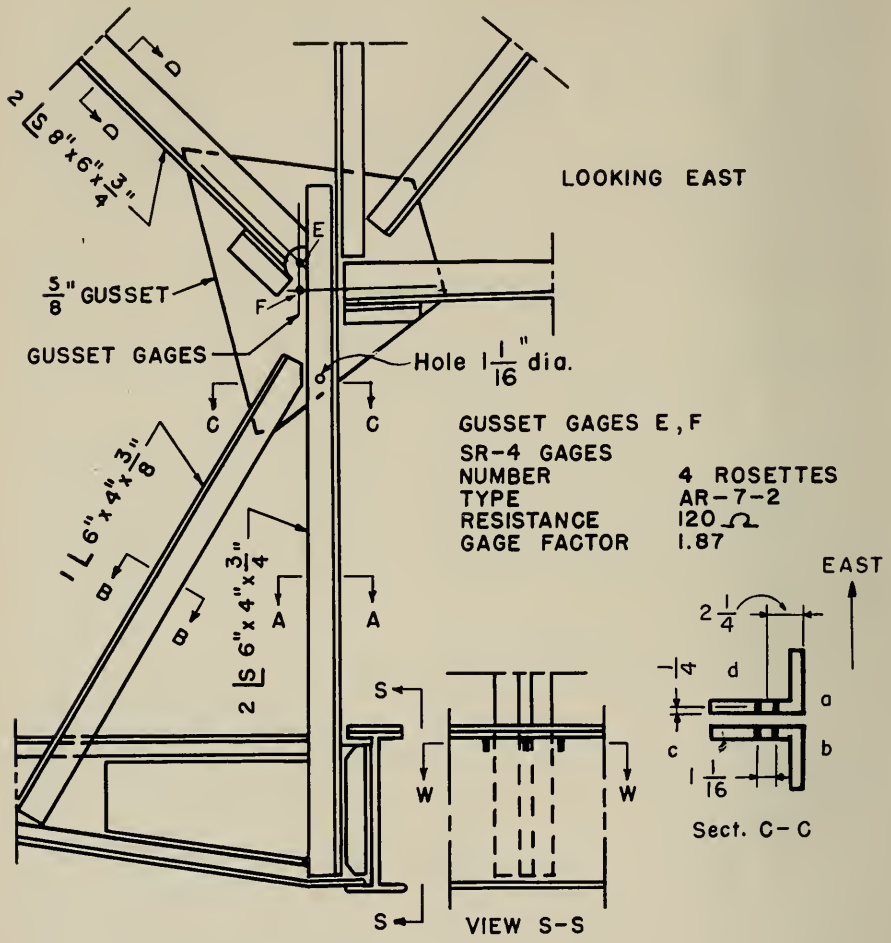
2. Bridges 1 and 2 of South Dock are identical.

3. Bridges 1,2. No record of repairs before 1941. Repairs in 1941 not described.

4. Bridges 3, 4. No record of repairs before 1944.

5. First regular inspection record available North Dock Bridges 1946
South Dock Bridges 1952

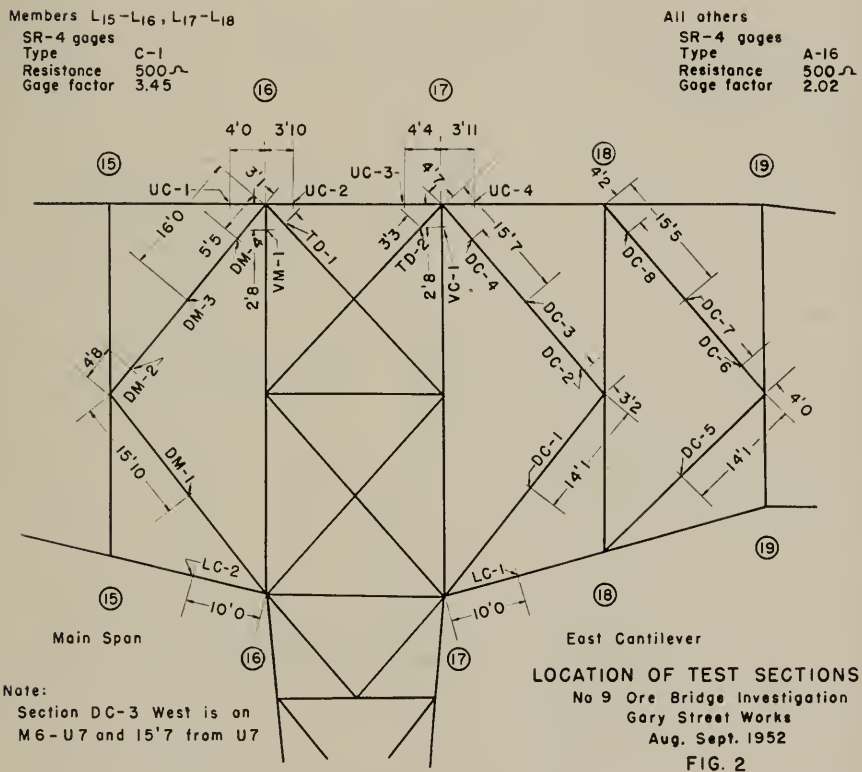
6. Above data furnished by American Bridge Division.



Section of continuous stringer
C.Pl. $10\frac{1}{2}$" x $\frac{1}{2}$" (top)
30 CB 108
See Fig. 30 for measured stresses

Notes:
1. All gages .31" from back or toe of angle except in section c-c.
2. See Figures 10-16 incl. and 30 for measured stresses.
and SR-4 gages

FIG. 1 GAGE LOCATIONS. CROSS FRAME AT L_{18}

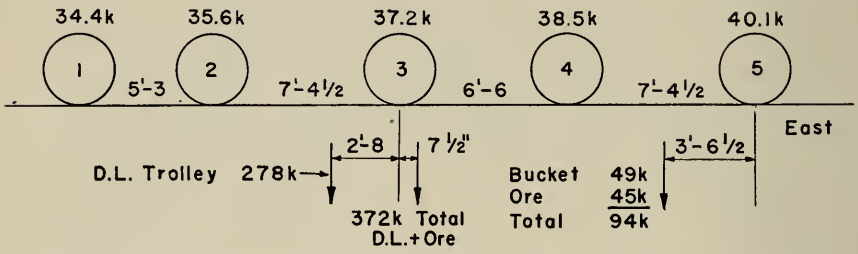


Note:
Section DC-3 West is on M6-U7 and 15'7 from U7

LOCATION OF TEST SECTIONS
No 9 Ore Bridge Investigation
Gary Street Works
Aug. Sept. 1952

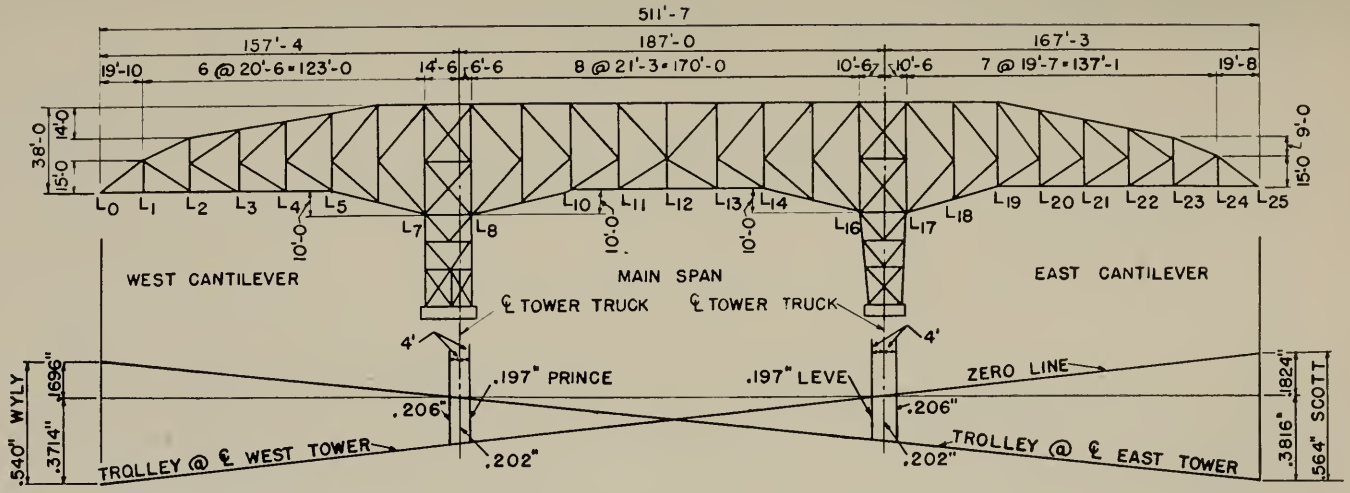
FIG. 2

1. Trolley Loads From Detail Weight Estimate
   Drwg. 8121-TA
   Date: 1-7-47

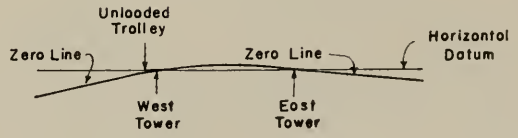


2. Trolley Loads Assumed On Stress Sheet
   Drwg. 8121-S4
   Date: 4-2-47
   Equal wheel loads of 38 kips assumed in design.

FIG. 3 TROLLEY LOADING DIAGRAMS



NOTE: 1. MEASUREMENTS SHOWN IN THIS FIGURE ARE DUE TO A TROLLEY WITH AN EMPTY BUCKET.
2. ALL DEFLECTIONS IN SUBSEQUENT FIGURES ARE REFERRED TO THE ZERO LINE SHOWN IN THIS FIGURE AS A BASE, AND NOT TO A HORIZONTAL DATUM.
3. THE EXACT SLOPE AND POSITION OF THE ZERO LINE ARE NOT KNOWN.



Sketch a
Showing actual character of zero line

FIG. 4 MEASUREMENTS OF STATIC DEFLECTIONS BY SURVEYING INSTRUMENTS

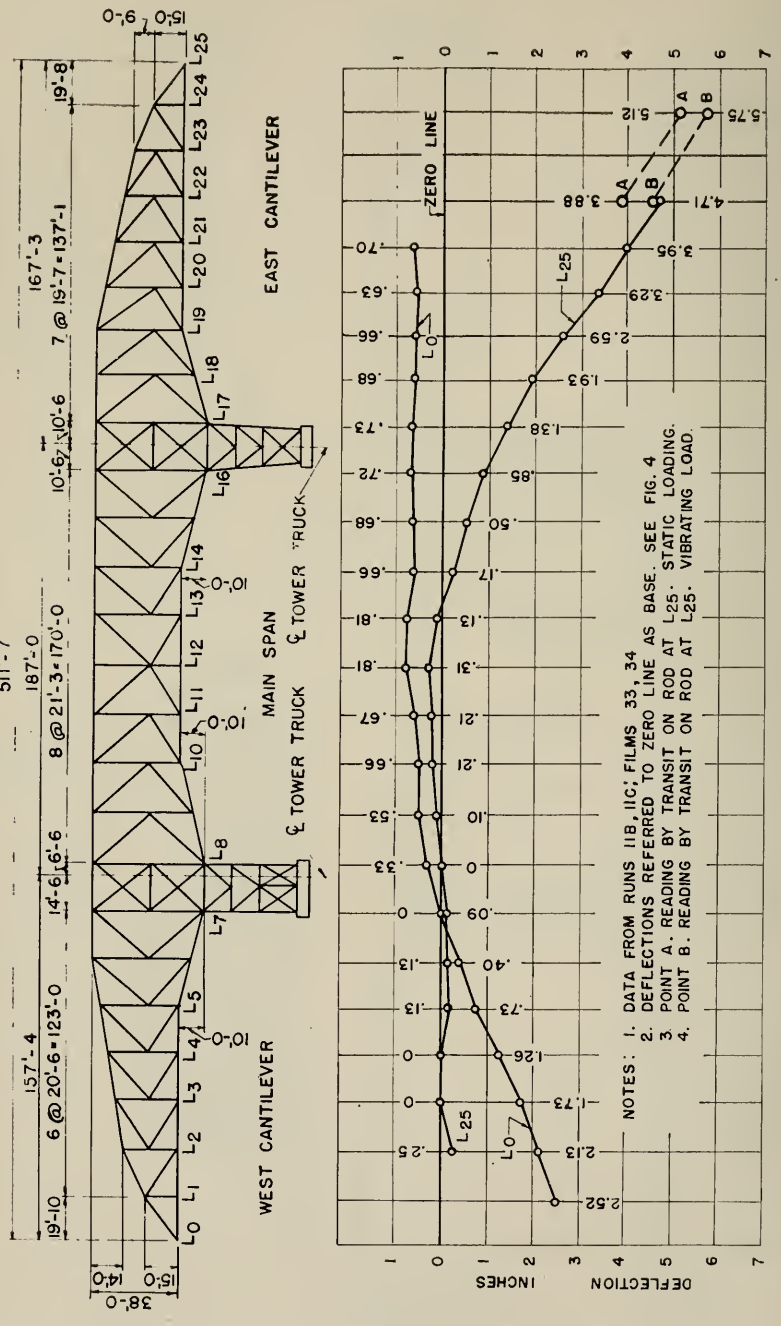
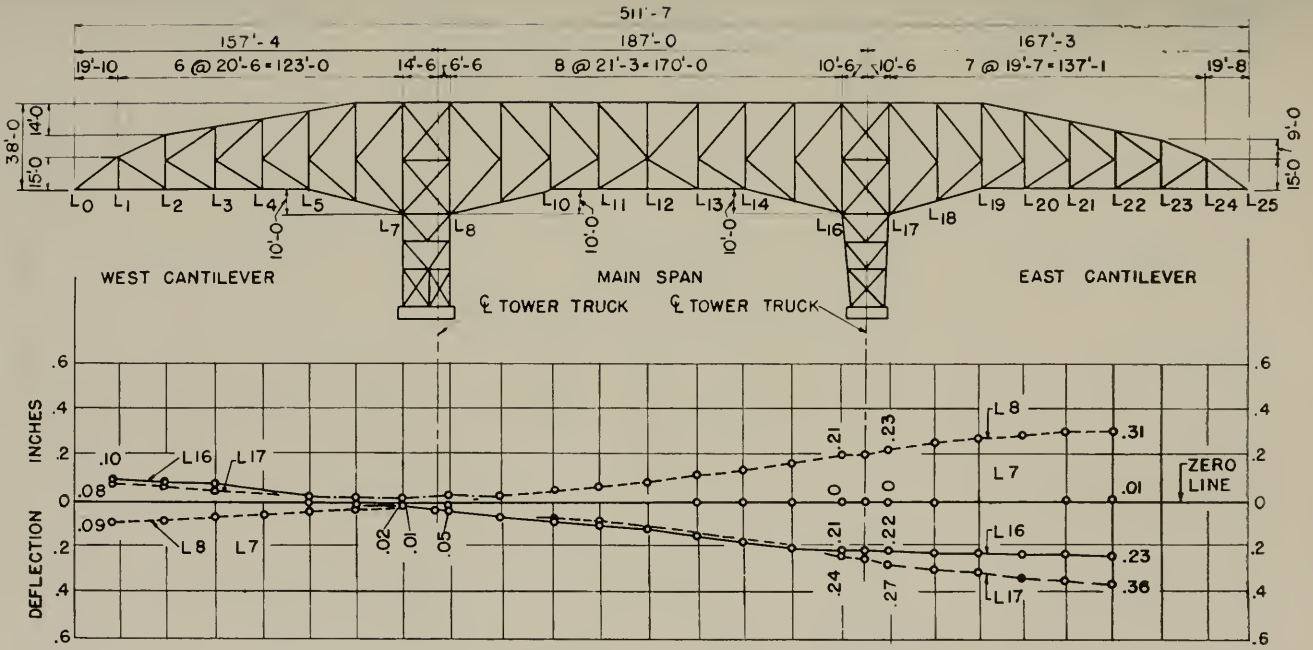

EAST CANTILEVER
MAIN SPAN
WEST CANTILEVER
℄ TOWER TRUCK
℄ TOWER TRUCK
ZERO LINE
DEFLECTION
INCHES
NOTES: 1. DATA FROM RUNS IIB, IIC; FILMS 33, 34
2. DEFLECTIONS REFERRED TO ZERO LINE AS BASE. SEE FIG. 4
3. POINT A. READING BY TRANSIT ON ROD AT L25. STATIC LOADING.
4. POINT B. READING BY TRANSIT ON ROD AT L25. VIBRATING LOAD

FIG. 5 INFLUENCE LINE FOR DEFLECTION OF L_0 AND L_{25} WITH LOADED TROLLEY



NOTES: 1. DATA FROM RUNS 11B, 11C; RUNS 33, 34.
2. THE INFLUENCE LINES IN THIS FIGURE ARE FOR MEASUREMENTS TAKEN ON THE TOWER TRUCKS AT POINTS 4ft. EAST OR WEST OF THE ℄ TOWER TRUCK.
3. SEE FIG. 4 FOR LOCATING ZERO LINE.
4. VIBRATING LOADS

FIG. 6 INFLUENCE LINE FOR DEFLECTION OF L_7, L_8, AND L_{16}, L_{17} WITH LOADED TROLLEY

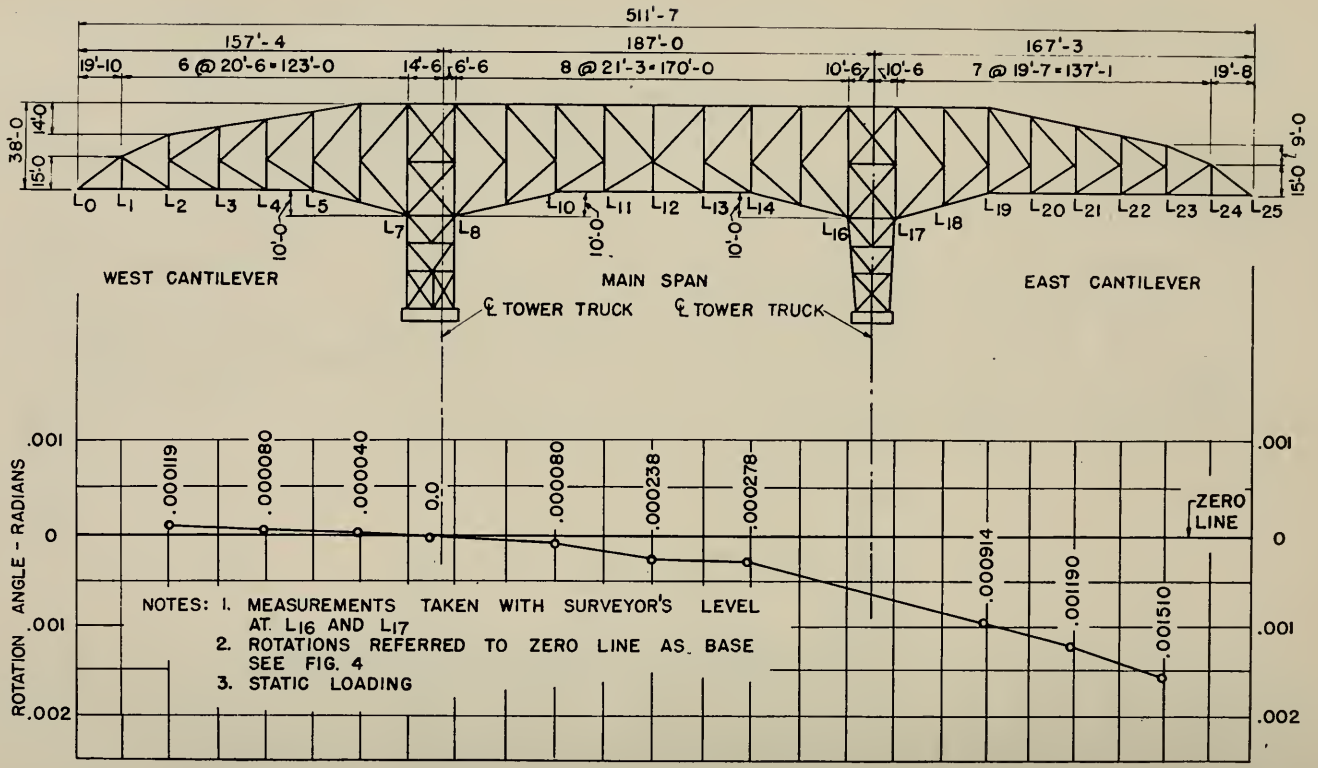


FIG. 7 INFLUENCE LINE FOR ROTATION OF EAST TOWER AT PLANE OF L_{16}-L_{17} WITH LOADED TROLLEY

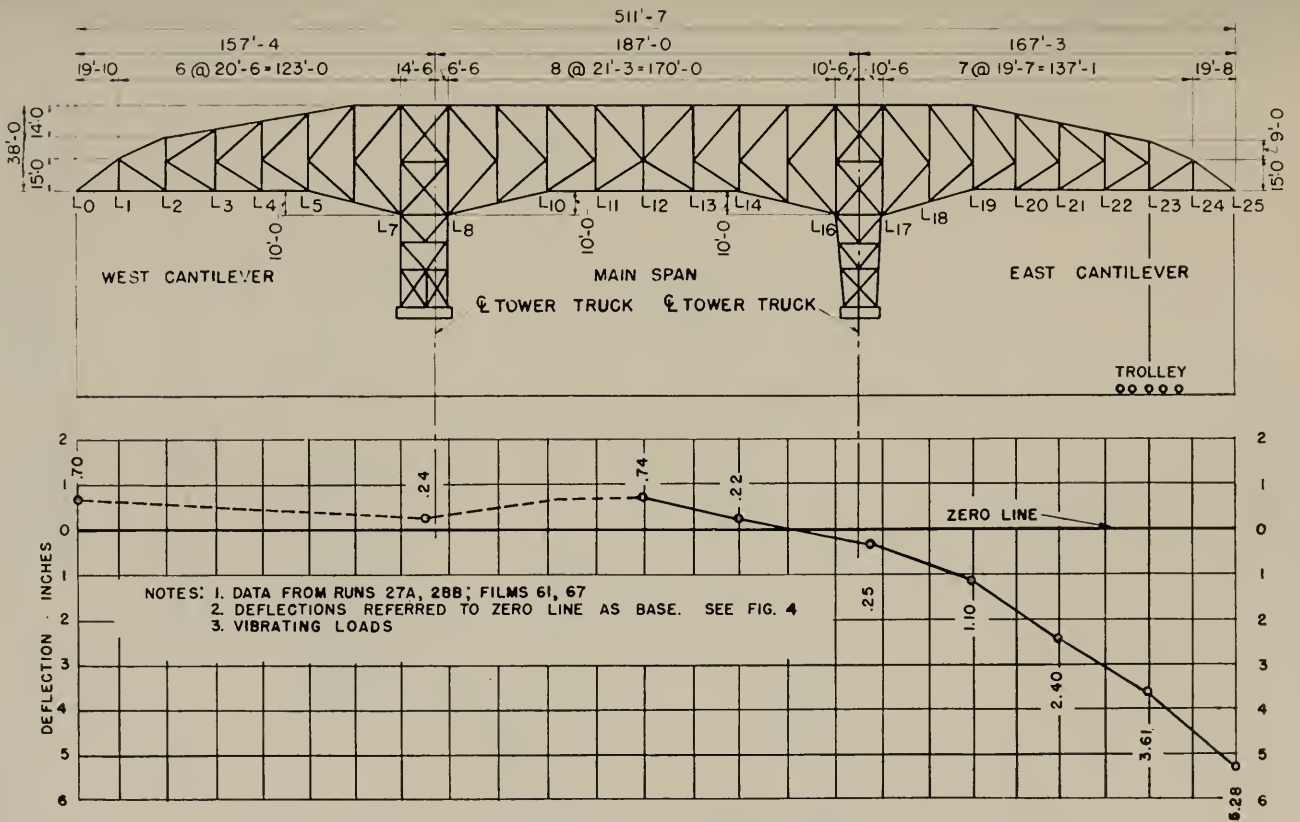
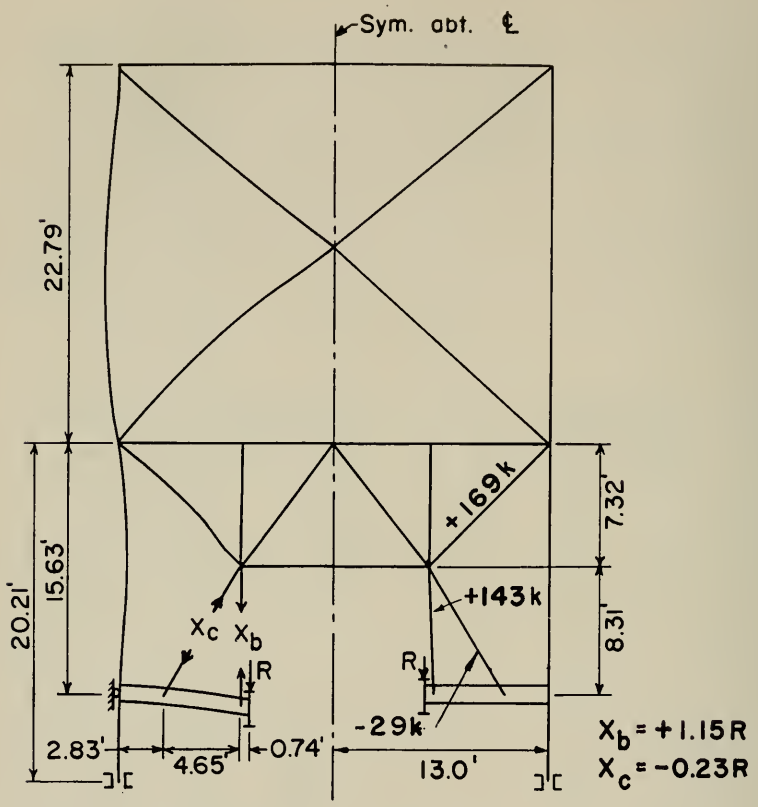


FIG. 8 DEFLECTION OF BRIDGE FOR LOADED TROLLEY AT L_{23}



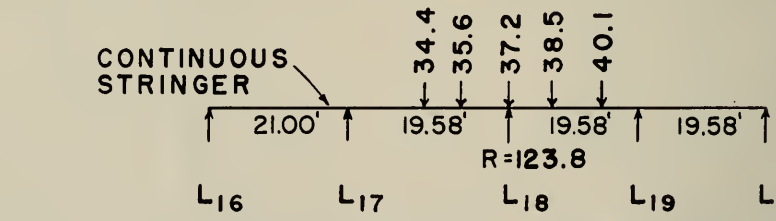
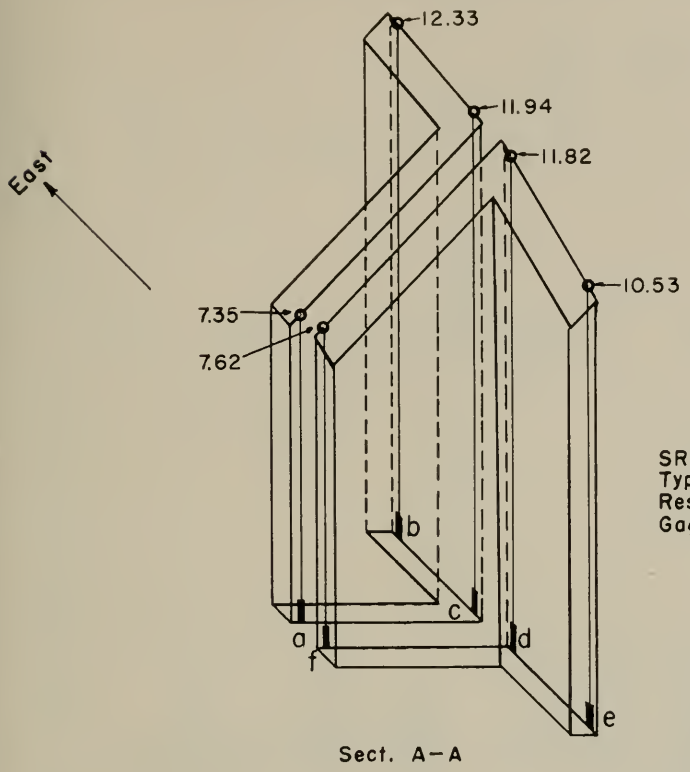


FIG. 9 COMPUTED L.L. STRESSES CROSS FRAME AT L_{18}



Sect. A–A

SR–4 gages 6
Type C–1
Resistance 500
Gage factor 3.45

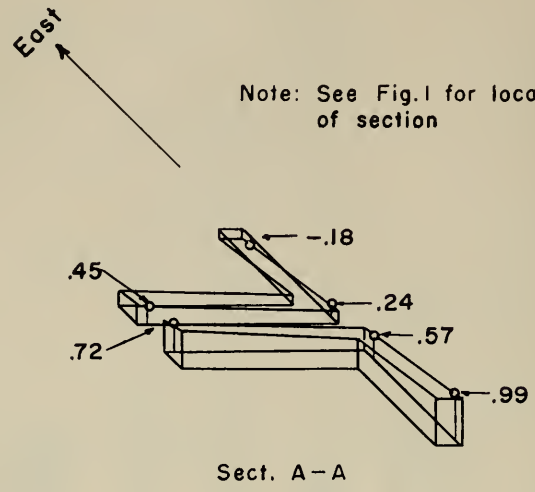
Note: See Fig. 1 for location of sect.

Total stress in hanger

Average unit stress				Area		Stress
(7.14 + 11.35) .50	=	9.245	x	3.937	=	36.40
(12.06 + 11.61) .50	=	11.835	x	3.0	=	35.51
(7.245 + 11.225) .50	=	9.235	x	3.937	=	36.37
(10.125 + 11.655) .50	=	10.39	x	3.0		32.6
						+ 140.95 kips Tension

Loading: Trolley with loaded bucket at L_{18}

FIG. 10 MEASURED STRESS IN L_{18} HANGER



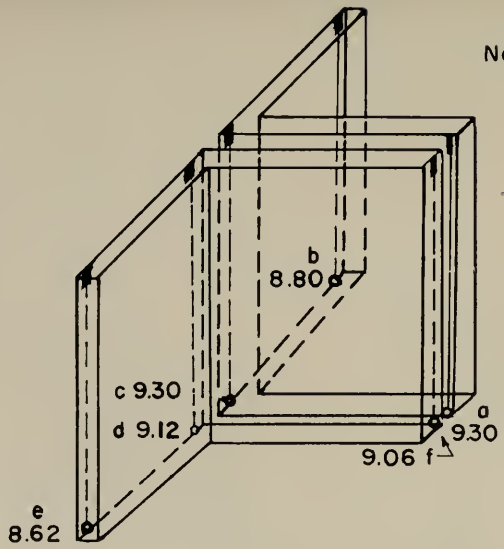
Total stress in hanger

Average unit stress		Area		Stress
(.4195 + .2615).50 =	.3405	x 3.937	=	1.34
(.2065 + .2895).50 =	.0415	x 3.0	=	.12
(.7655 + .6625).50 =	.714	x 3.937	=	2.81
(.6155 + 1.0355).50 =	.8255	x 3.0	=	2.48
				- 6.75 kips Comp.

Loading: Trolley with loaded bucket at ℄ East Tower

FIG. 11 MEASURED STRESS IN L_{18} HANGER

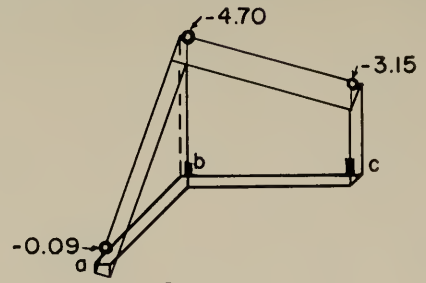
Note: see fig.1 for location of sections.



Section D-D

Total stress in diagonal

Average unit stress		Area		Stress
(8.80 + 9.30).50	=	9.05 x 4.50	=	+ 40.70
		9.26 x 5.44	=	+ 50.40
(9.11 + 9.02).50	=	9.07 x 5.44	=	+ 49.40
(9.12 + 8.62).50	=	8.87 x 4.50	=	+ 39.90
				+180.40 kips Tension



Section B-B

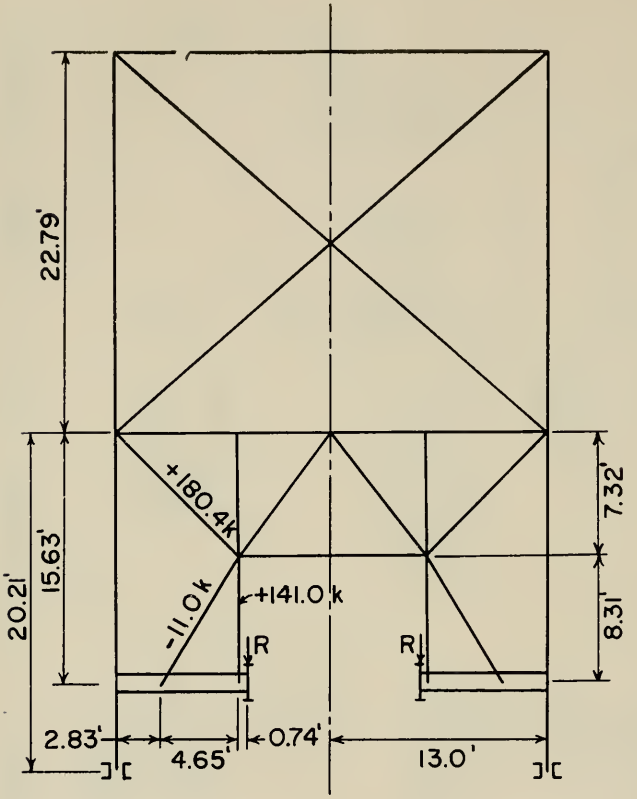
Total stress in brace

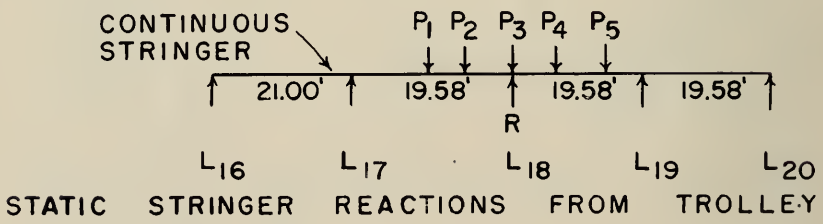
Average unit stress		Area		Stress
(4.55 + 2.83).50	=	3.687 x 2.25	=	- 8.31
(4.26 + 0.35).50	=	2.30 x 1.36	=	- 3.13
		0.34 x 1.36	=	+ 0.46
				-11.00 kips Compression

SR-4 Gages

Type	C-1
Resistance	500
Gage Factor	3.45

FIG. 12 MEASURED STRESS IN L_{18} STRINGER BRACE & FRAME DIAGONAL

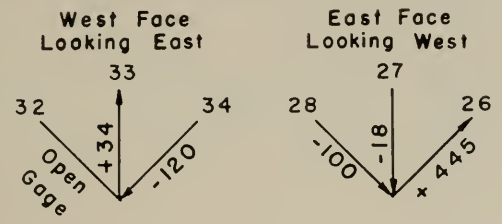


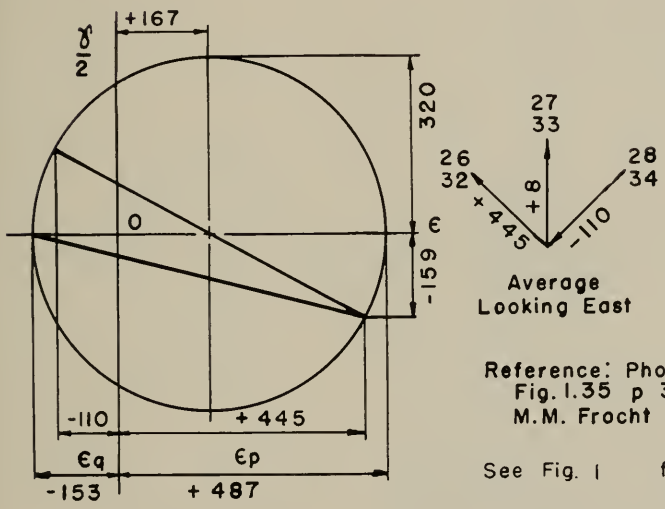


STATIC STRINGER REACTIONS FROM TROLLEY

FIG. 13 MEASURED L.L. STRESSES CROSS FRAME AT L_{18}

MEASURED STRAINS – POINT E





Reference: Photoelasticity
Fig. I.35 p 38 Vol. I
M.M. Frocht

See Fig. 1 for location

COMPUTED STRAINS

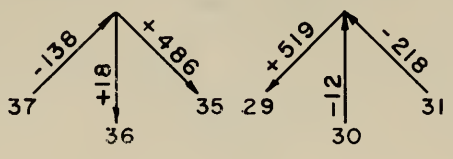
$$p = \frac{E(\epsilon p + \mu \epsilon q)}{1-\mu^2} = \frac{30{,}000{,}000\,[.000487 - .30(.000153)]}{1-(.30)^2} = 14{,}542 \text{ psi}$$

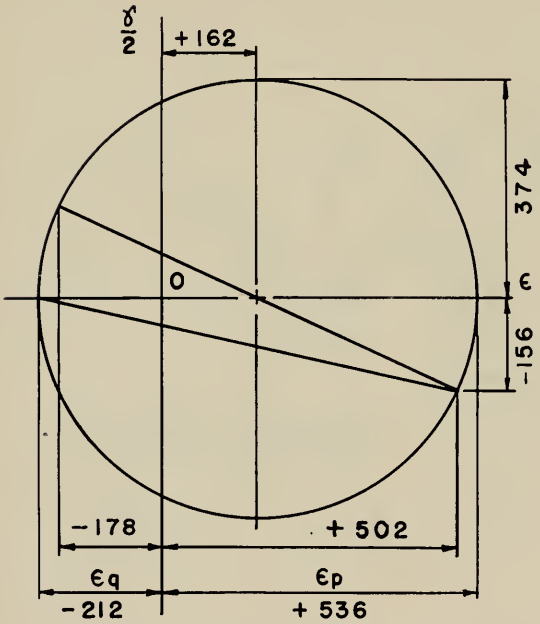
$$q = \frac{E(\epsilon q + \mu \epsilon p)}{1-\mu^2} = \frac{30{,}000{,}000\,[-.000153 + .30(.000487)]}{1-(.30)^2} = -210 \text{ psi}$$

$$\tau = (\epsilon p - \epsilon q)\,G = (.000487 + .000153)\,12{,}000{,}000 = 7{,}680 \text{ psi}$$

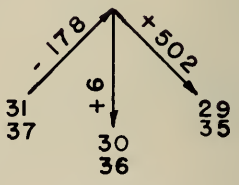
FIG. 14 MEASURED STRAINS IN GUSSET

MEASURED STAINS — POINT F





Strain Circle



Average
Looking East

COMPUTED STRAINS

$$p = \frac{30{,}000{,}000\,[\,.000536 - .30(.000212)\,]}{1-(.30)^2} = +15{,}576 \text{ psi}$$

$$q = \frac{30{,}000{,}000\,[\,.000212 - .30(.000536)\,]}{} = -1{,}530 \text{ psi}$$

$$\tau = (.000536 + .000212)\,12{,}000{,}000 = +8{,}976 \text{ psi}$$

FIG. 15 MEASURED STRAINS IN GUSSET

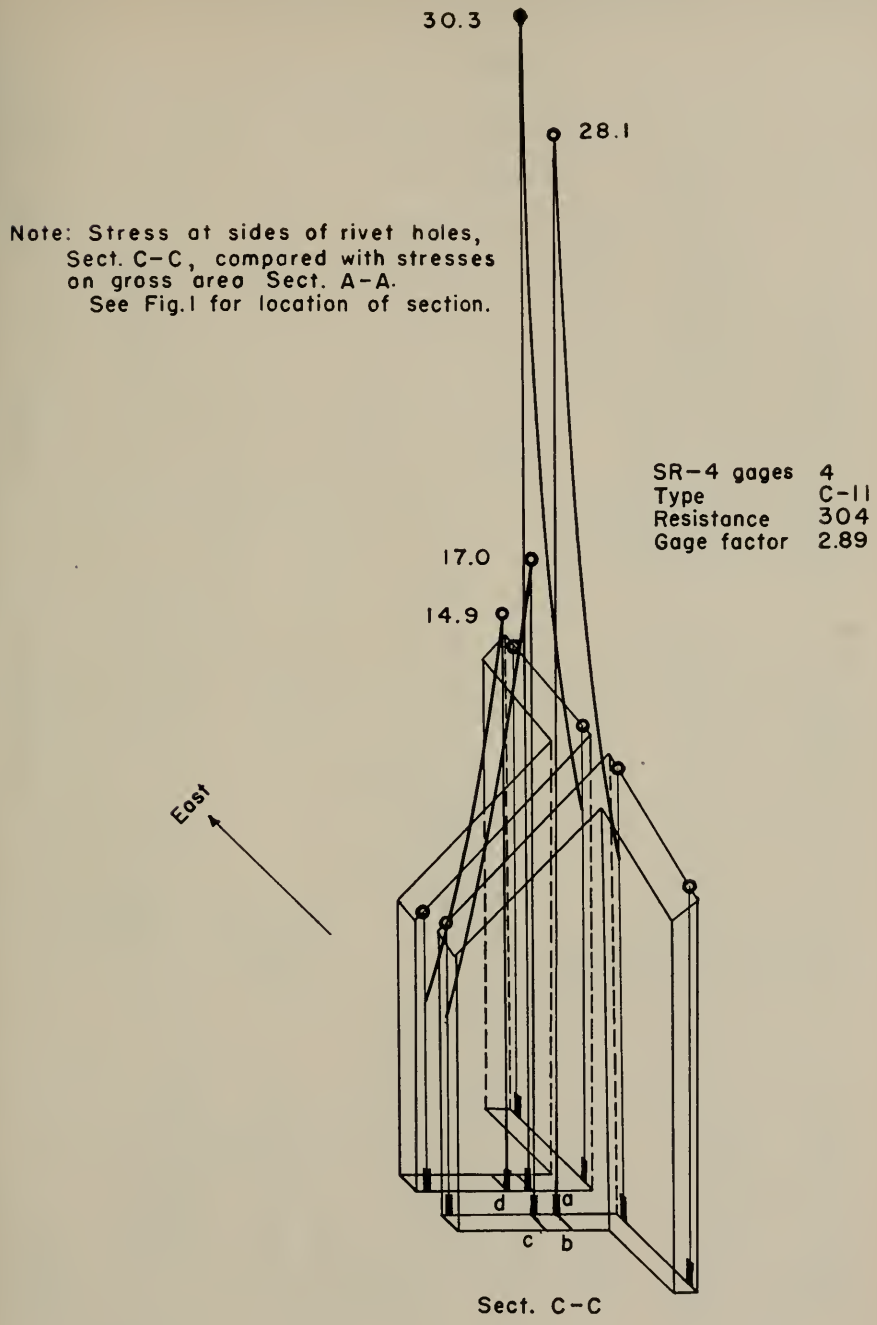
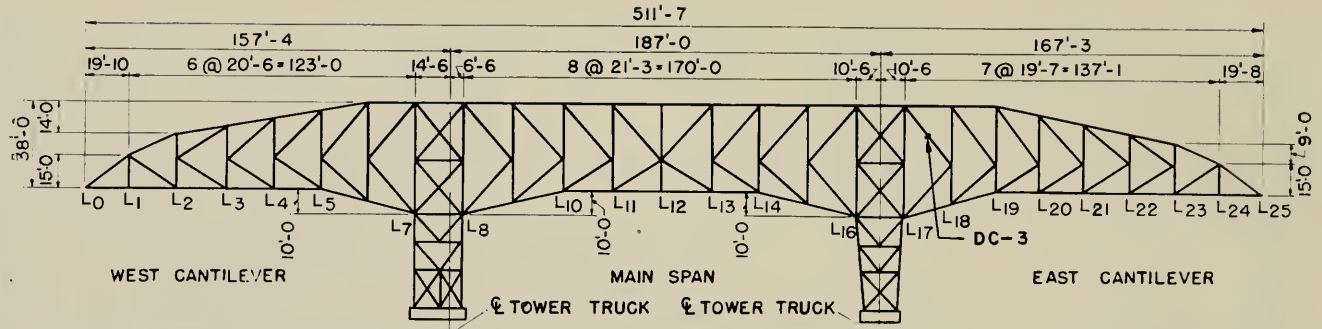
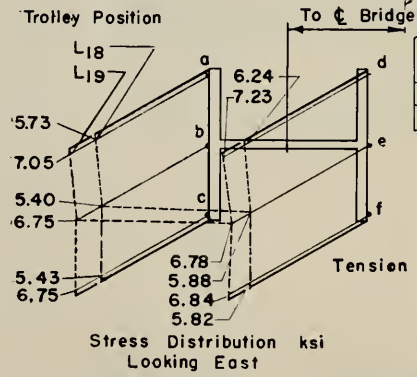


FIG. 16 MEASURED STRESSES AT SIDES OF HOLES IN L_{18} HANGER - SECT. C-C

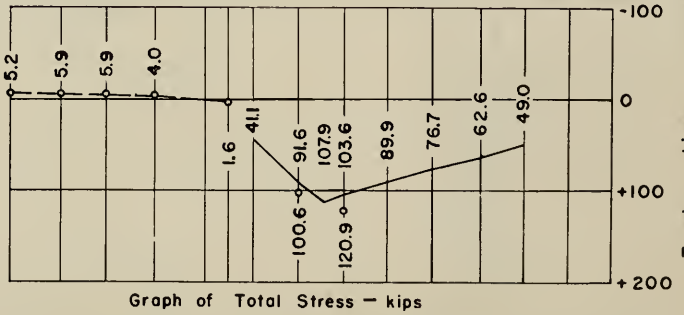




Stress Distribution ksi
Looking East

Member $U_{17}-M_{18}$
Sec. DC-3

Trolley Location	Total Stress
L_{19}	120.9
L_{18}	100.6



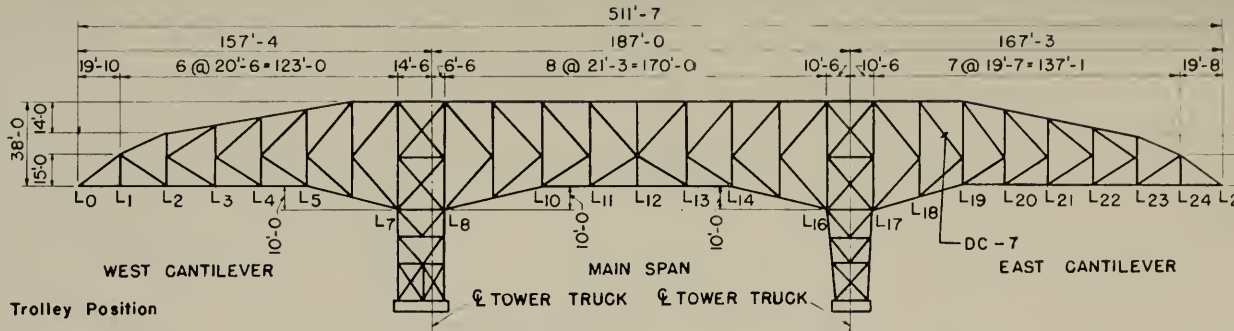
Graph of Total Stress — kips

Notes: 1. Stresses due to trolley with loaded bucket
2 Trolley location denotes position of center axle.

Legend: Measured values
Computed values

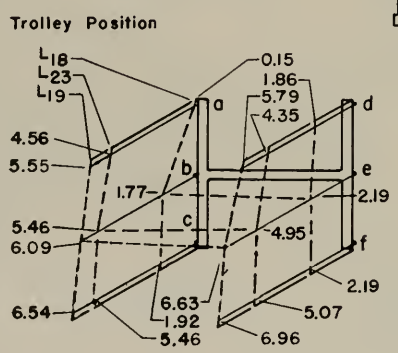
Section
10 CB 60
$A_g = 17.66\ in^2$

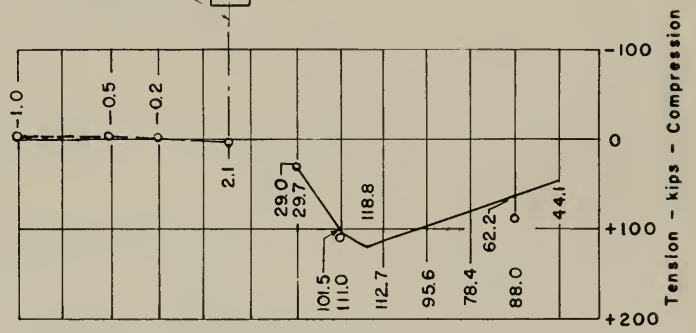
FIG. 17 MEASURED AND COMPUTED STATIC STRESSES



MEASURED STRESS

Trolley Location	Total Stress
L_{23}	87.98
L_{19}	110.98
L_{18}	29.69





Note: See Fig. 17 for notes and legend

Member $U_{18}-M_{19}$
Sec. DC-7

Section
10 CB 60
$A_g = 17.66\ in^2$

FIG. 18 MEASURED AND COMPUTED STATIC STRESSES

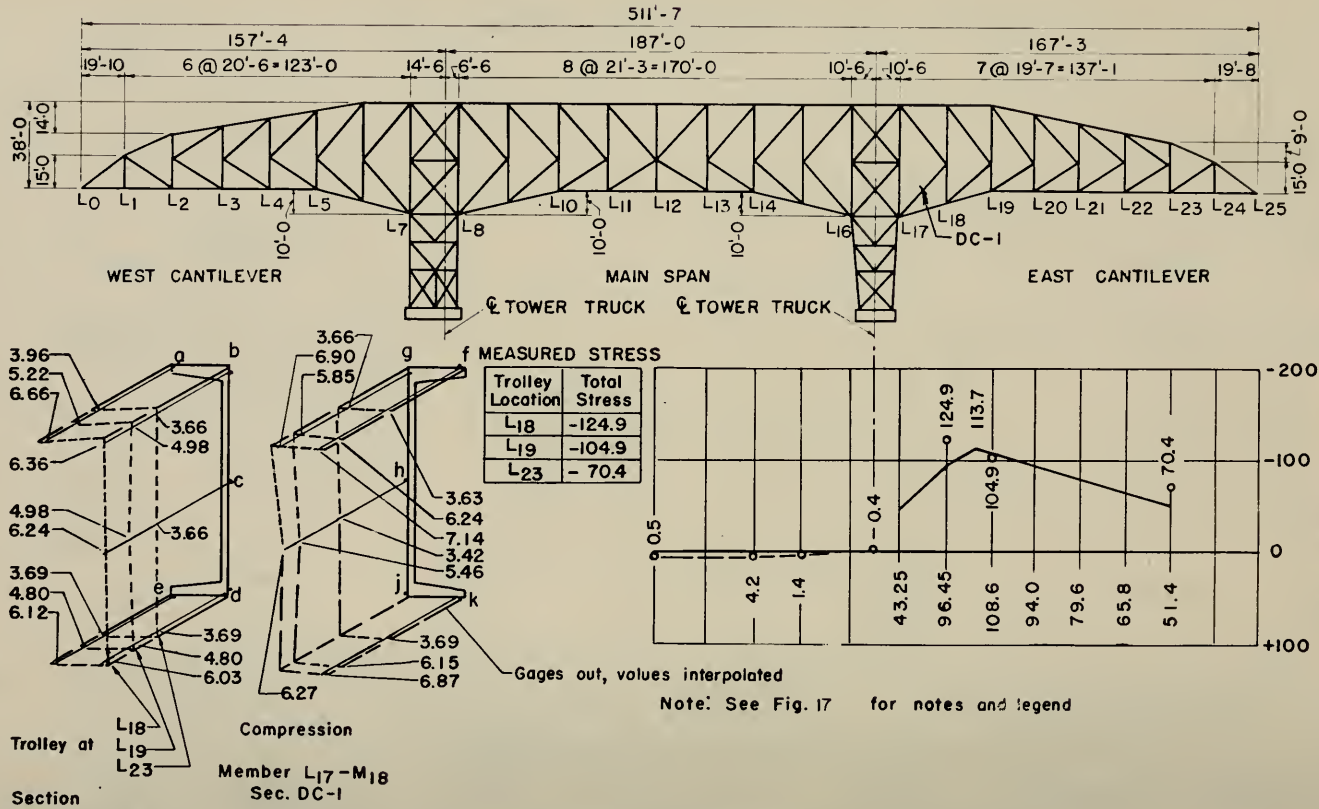
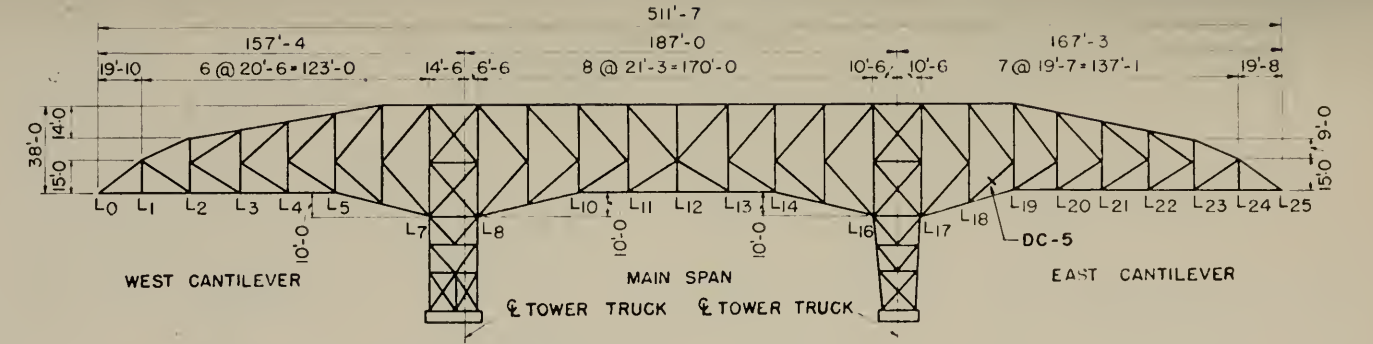
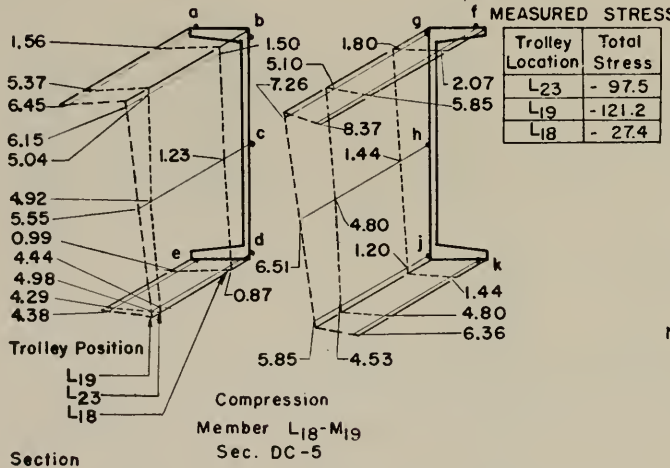


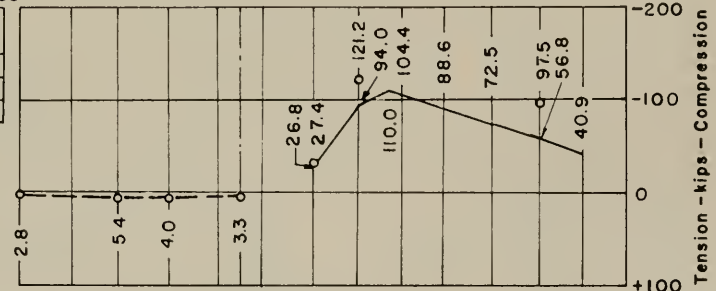
FIG 19 MEASURED AND COMPUTED STATIC STRESSES





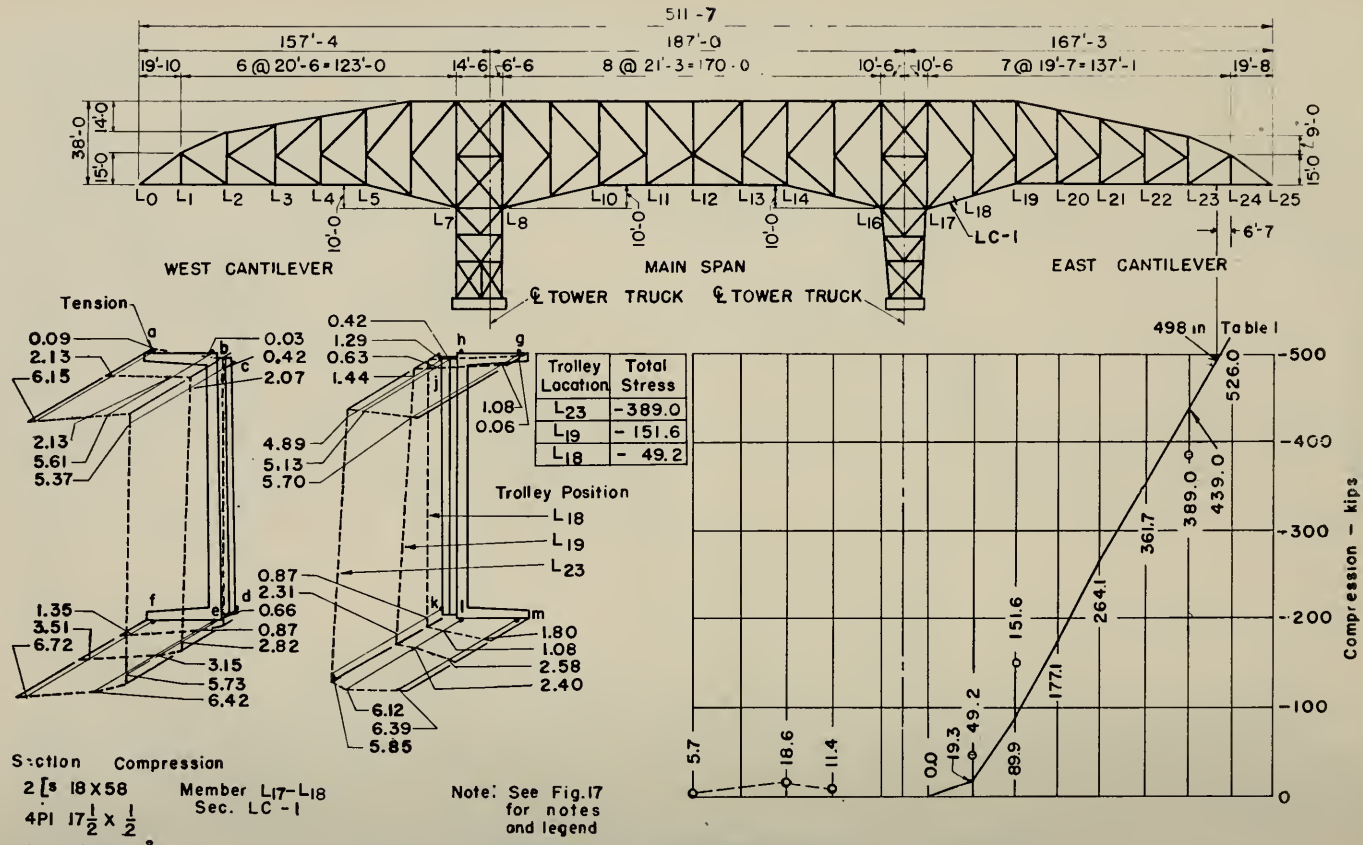
MEASURED STRESS

Trolley Location	Total Stress
L_{23}	- 97.5
L_{19}	-121.2
L_{18}	- 27.4



Note: See Fig. 17 for notes and legend

FIG. 20 MEASURED AND COMPUTED STATIC STRESSES



Trolley Location	Total Stress
L_{23}	-389.0
L_{19}	- 151.6
L_{18}	- 49.2

Section Compression

2 [s 18 X 58

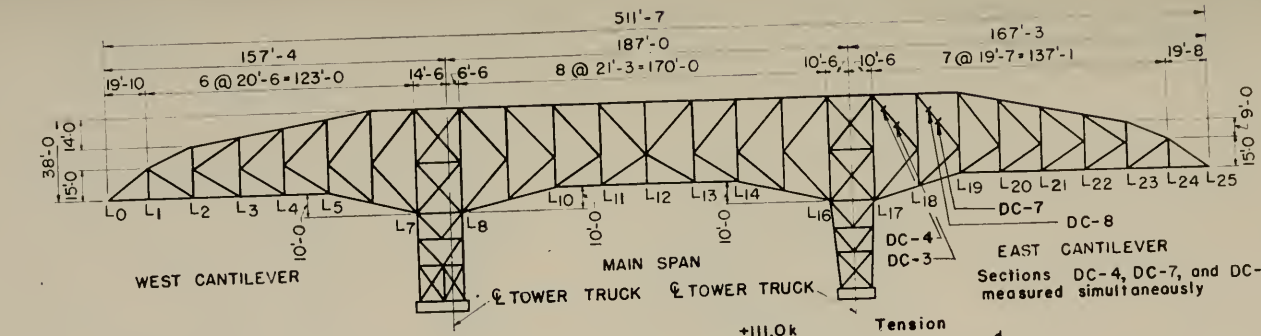
4Pl $17\frac{1}{2} \times \frac{1}{2}$

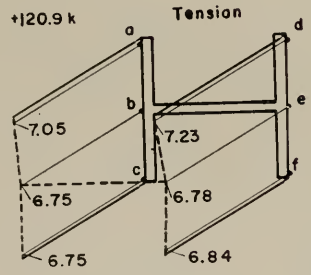
Ag. = 68.96 in.²

Member L_{17}-L_{18}
Sec. LC-1

Note: See Fig. 17 for notes and legend

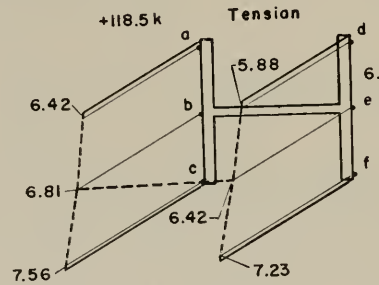
FIG. 21 MEASURED AND COMPUTED STATIC STRESSES



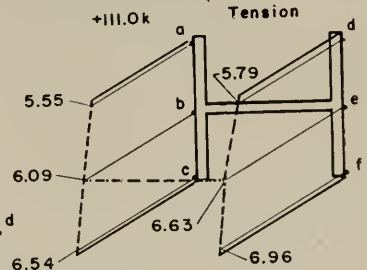


Member U_{17} - M_{18}
Sec. DC-3

Section
10 CB 60
Ag = 17 66 in²

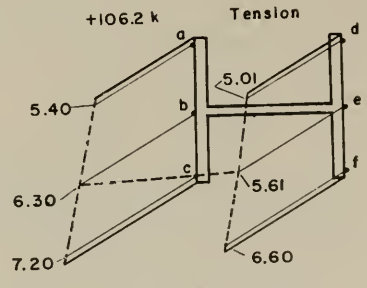


Member U_{17}-M_{18}
Sec. DC-4



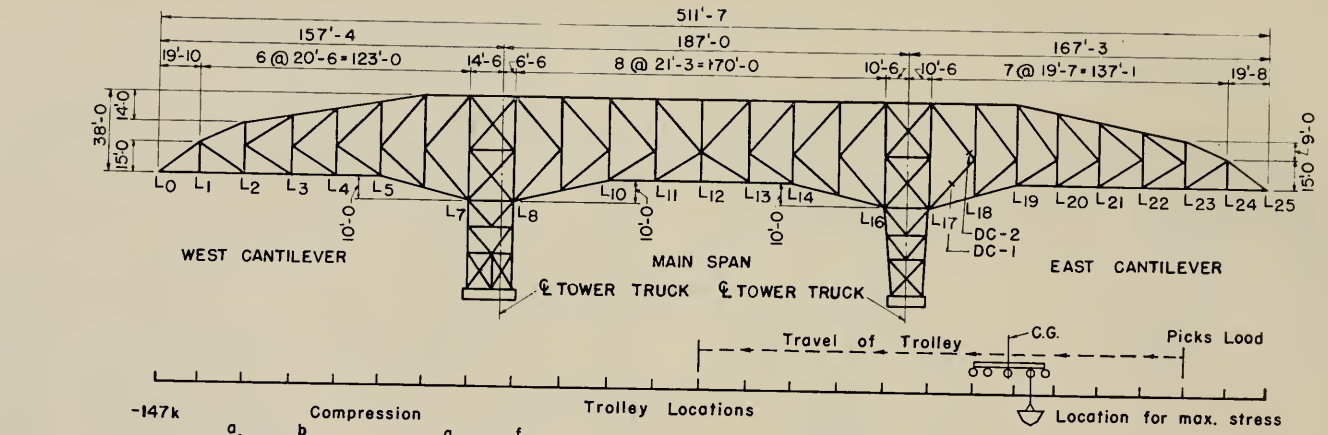
Member U_{18}-M_{19}
Sec. DC-7

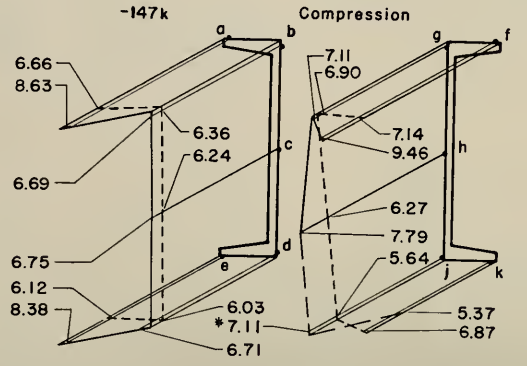
Section
10 CB 60
Ag.= 17.66in²



Member U_{18} - M_{19}
Sec. DC-8

FIG. 22 MEASURED STATIC STRESSES - LOADED TROLLEY AT L_{19}



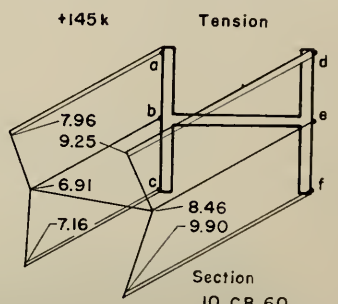


Section
2 [s 15 X 33 9
Ag. = 19 80 in²

Member L17 M18
Sec. DC-1

Notes for Figs. 23 to 29 incl.

1. All stresses shown are at gage locations.
2. All stresses indicated are in ksi.
3. * gage out, value interpolated. — — — —
4. Static stresses, max. - - - -
5. Dynamic stresses, max. ———



Section
10 CB 60
Ag. = 17.66 in²

Member U17 M18
Sec. DC-2

FIG. 23 MEASURED DYNAMIC AND STATIC STRESSES

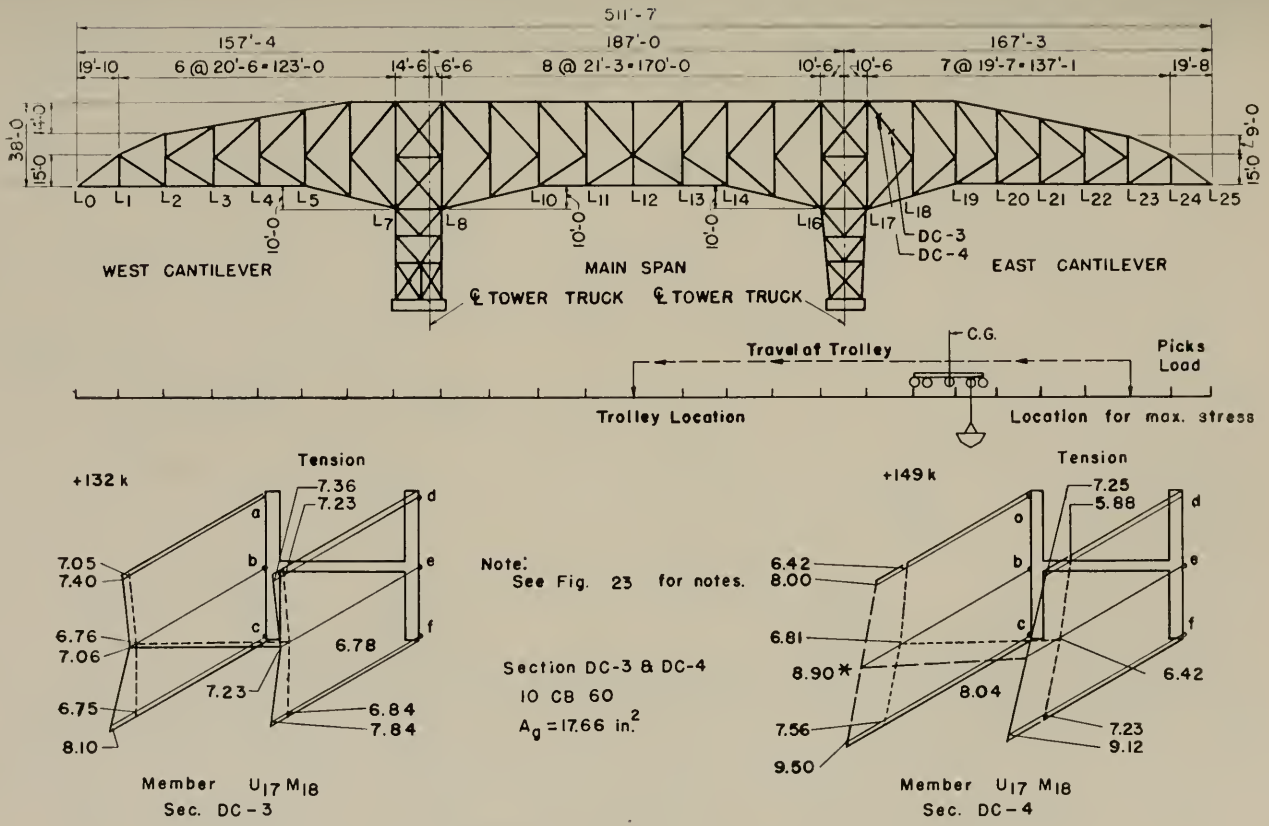
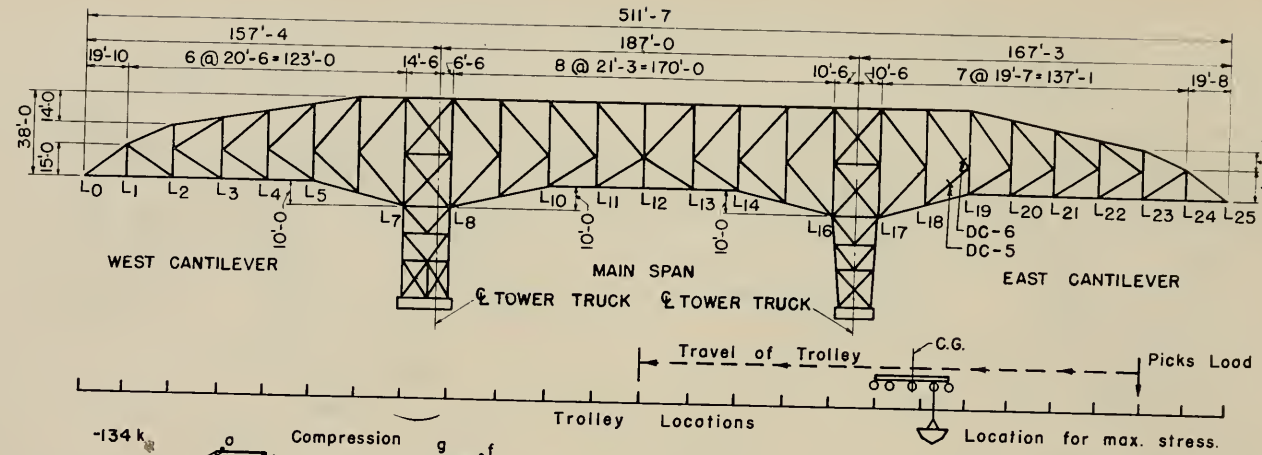
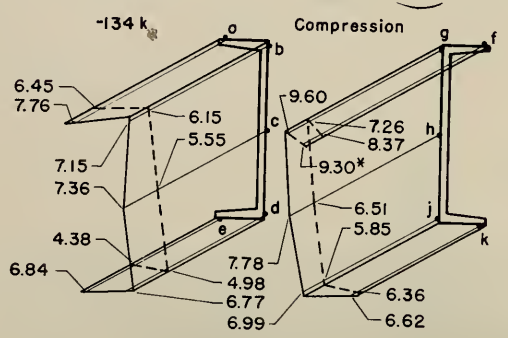


FIG. 24 MEASURED DYNAMIC AND STATIC STRESSES

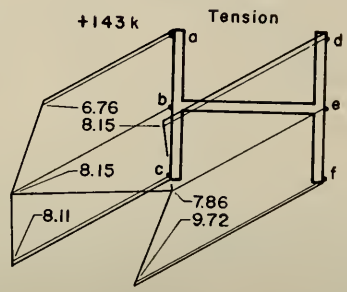




Section
2 [12 X 30.0
Ag = 17.58 in²

Member L_{18} M_{19}
Sec. DC-5

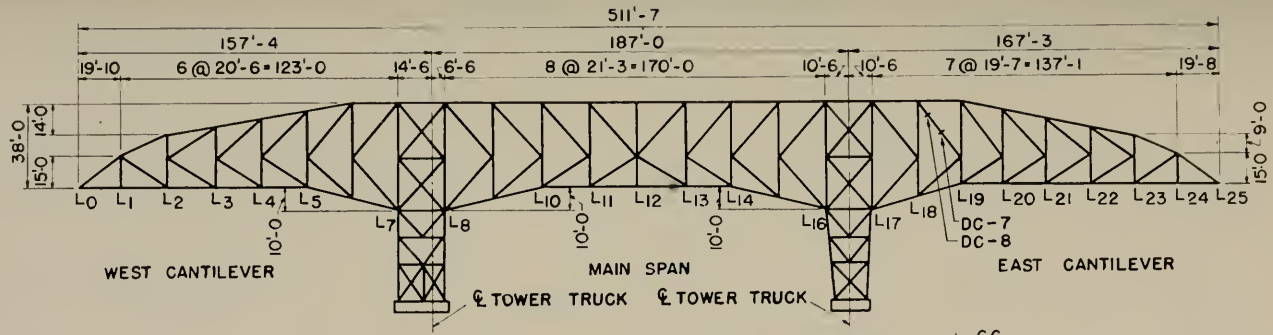
Note:
See Fig. 23 for notes.

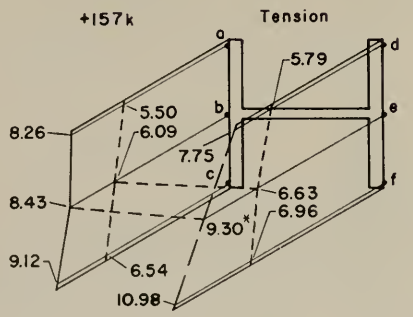


Section
10 CB 60
A_g = 17.66 in.²

Member U_{18} M_{19}
Sec. DC-6

FIG. 25 MEASURED DYNAMIC AND STATIC STRESSES

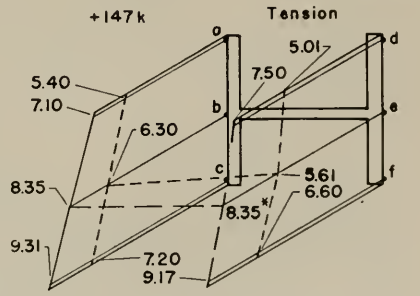




Member U_{18} M_{19}
Sec. DC-7

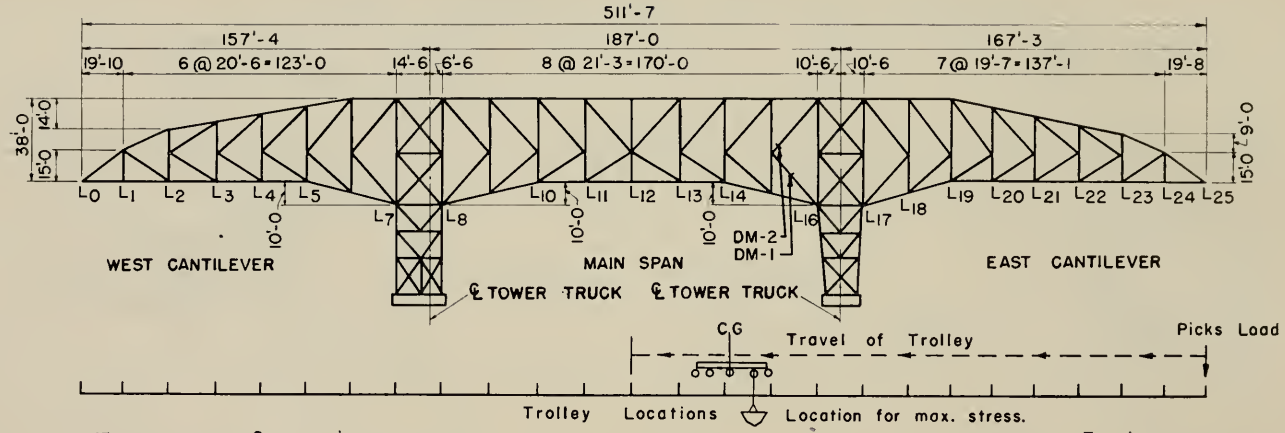
Note:
See Fig. 23 for notes.

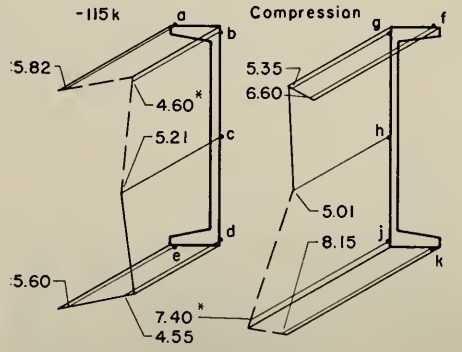
Sectin
10 CB 60
$A_g = 17.66$ in.^{2}



Member U_{18} M_{19}
Sec. DC-8

FIG. 26 MEASURED DYNAMIC AND STATIC STRESSES

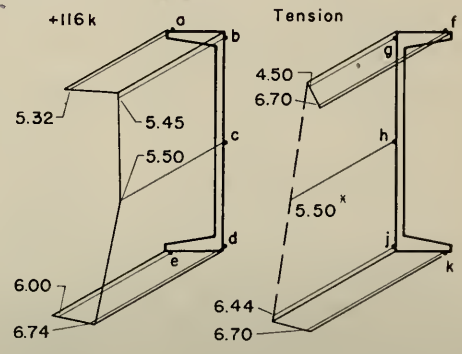




Member L_{16} M_{15}
Sec. DM-1

Note:
See Fig. 23 for notes.

Section
2 [s 15 X 33.9
Ag. = 19.80 in²



Member U_{16} M_{15}
Sec. DM-2

FIG. 27 MEASURED DYNAMIC STRESSES

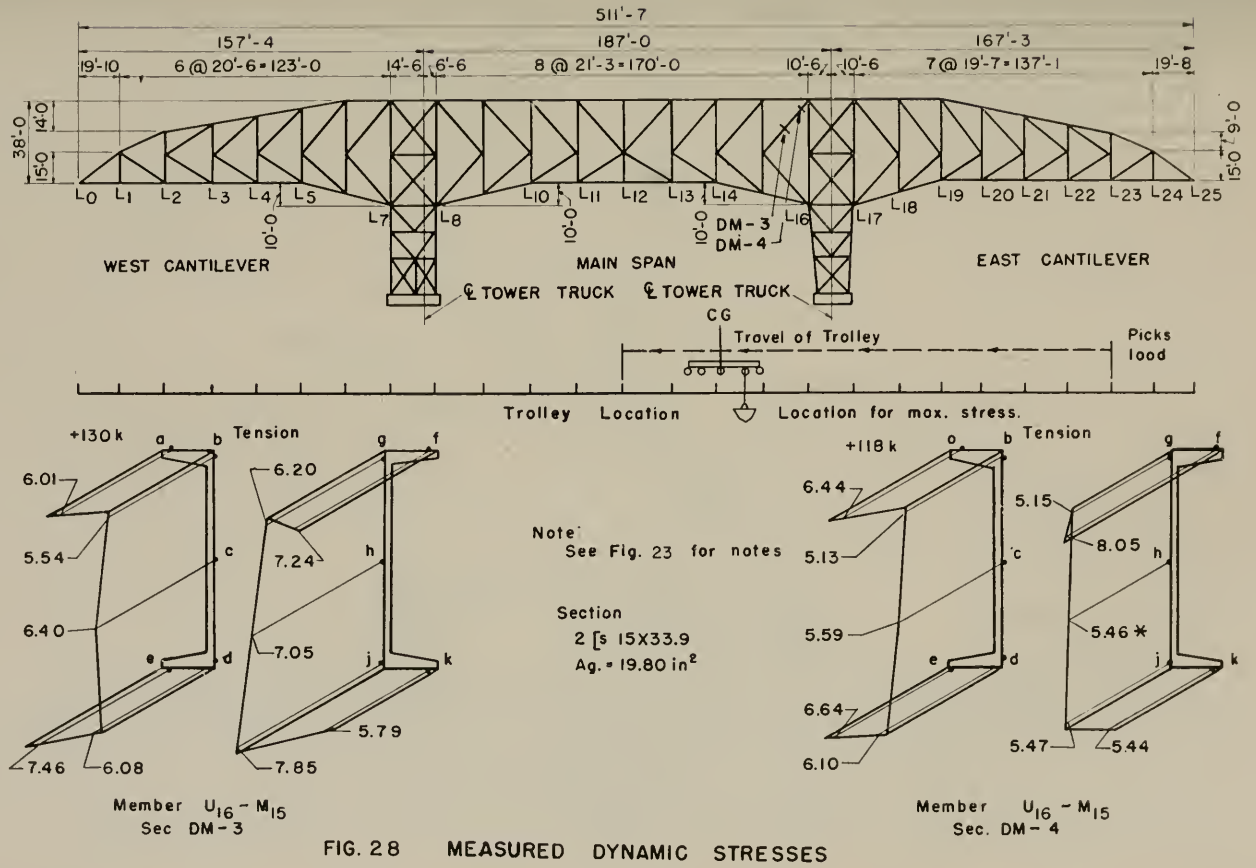
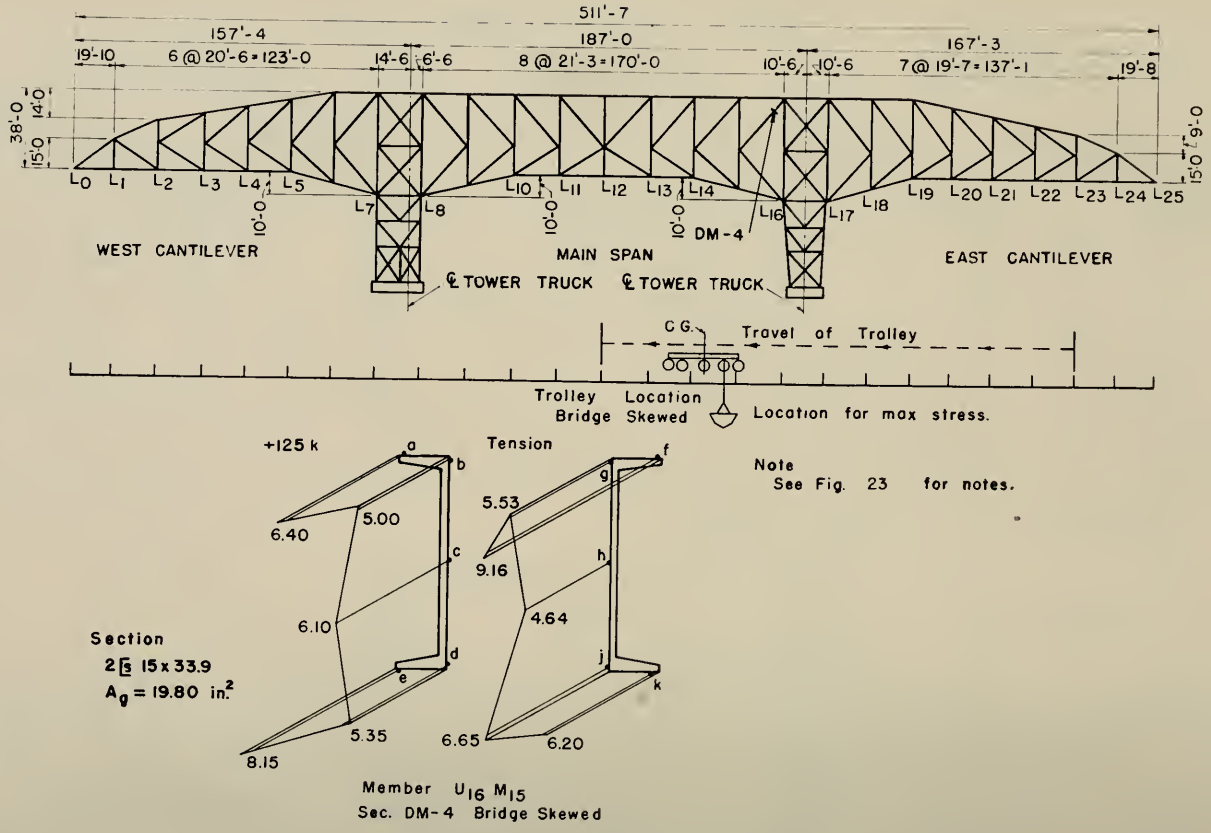


FIG. 28 MEASURED DYNAMIC STRESSES

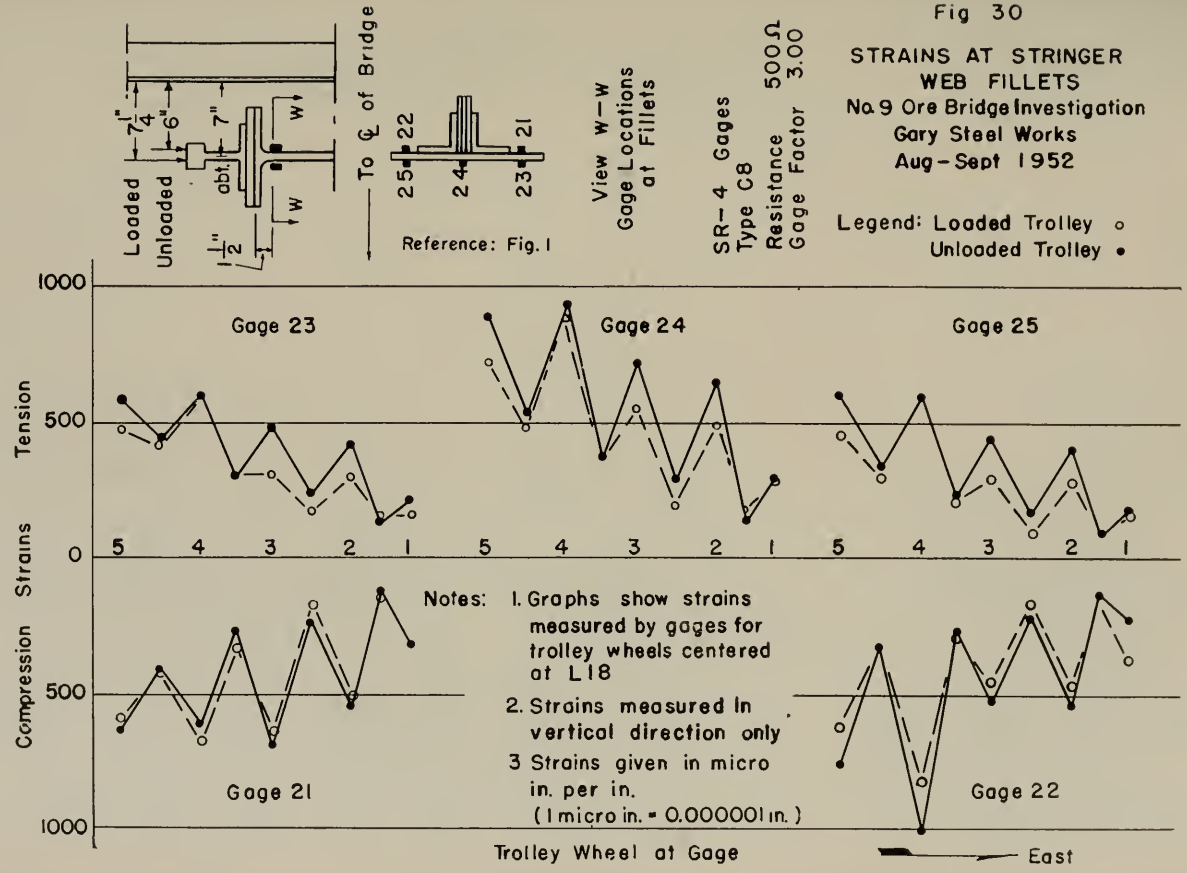


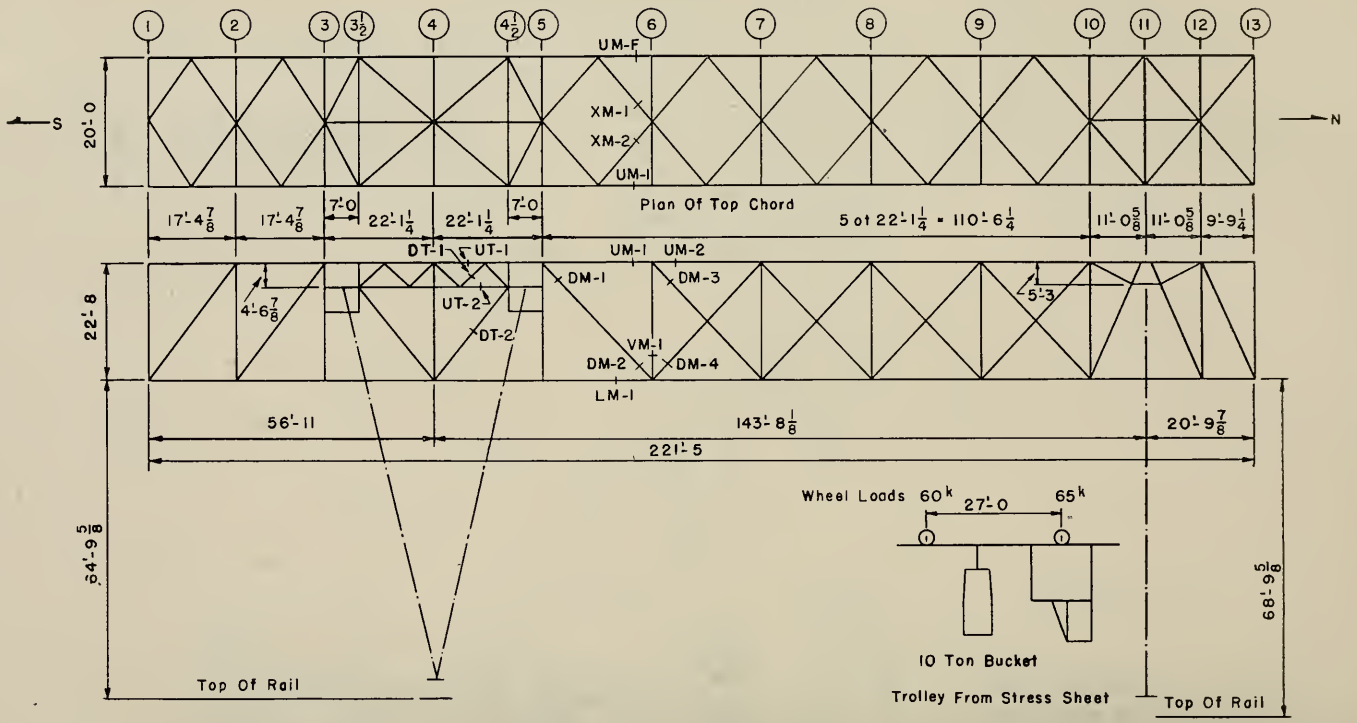
Note
See Fig. 23 for notes.

FIG. 29 MEASURED DYNAMIC STRESSES

Fig 30

STRAINS AT STRINGER WEB FILLETS
No. 9 Ore Bridge Investigation
Gary Steel Works
Aug – Sept 1952





SR-4 GAGE-SECTION LAYOUT FOR STRESS MEASUREMENTS IN NO.2 ORE BRIDGE

L.T. Wyly, M.B. Scott

FIG. 31

ORE BRIDGE INVESTIGATION
Edgar Thomson Works
U.S. Steel Corporation
Purdue Univ. Engineering Exp. Sta.

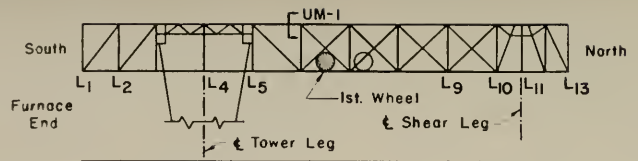
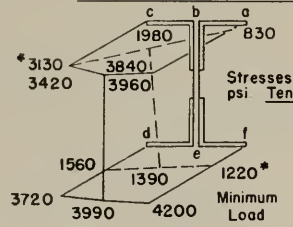


FIG. 32

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses – – – –
* Gage out, value interpolated

SUMMARY OF MEASURED STRESSES
SECTION UM-1
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

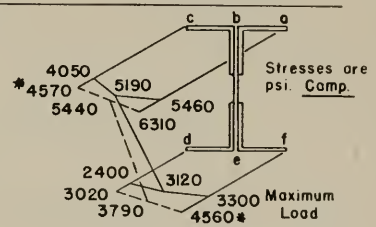


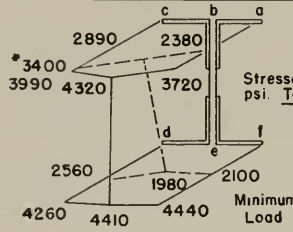
Location Of Trolley (1st. Wheel)
6' from L1 toward L2 — Static ——— at L6
In panel 2-3 – – – Dynamic — about 7' south of L6

Measured Total Live Load in Member
149,150 lb. T. ——— Static ——— 154,500 lb.C.
63,800 lb. T. – – – Dynamic ——— 175,000 lb.C.

Maximum Stress Range
3840 psi. Tens. ——— Gage d ——— 5,460 Comp.

SEC. UM-1 SPAN SKEWED WEST



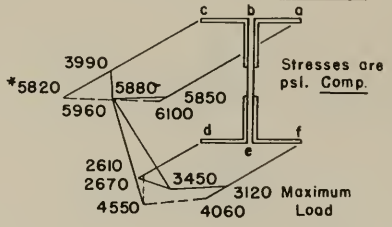


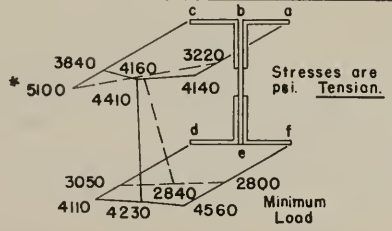
Location Of Trolley (1st. Wheel)
6' from L1 toward L2 — Static ——— at L6
In panel 2-3 – – – Dynamic — about 7' south of L6

Measured Total Live Load in Member
163,120 lb T. ——— Static ——— 171,200 lb.C.
92,400 lb. T. – – – Dynamic ——— 194,500 lb.C.

Maximum Stress Range
4,320 psi. Tens. ——— Gage b ——— 5,880 psi. Comp.

SEC. UM-1 SPAN SQUARE



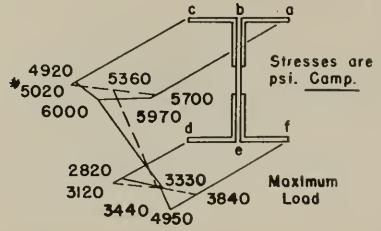


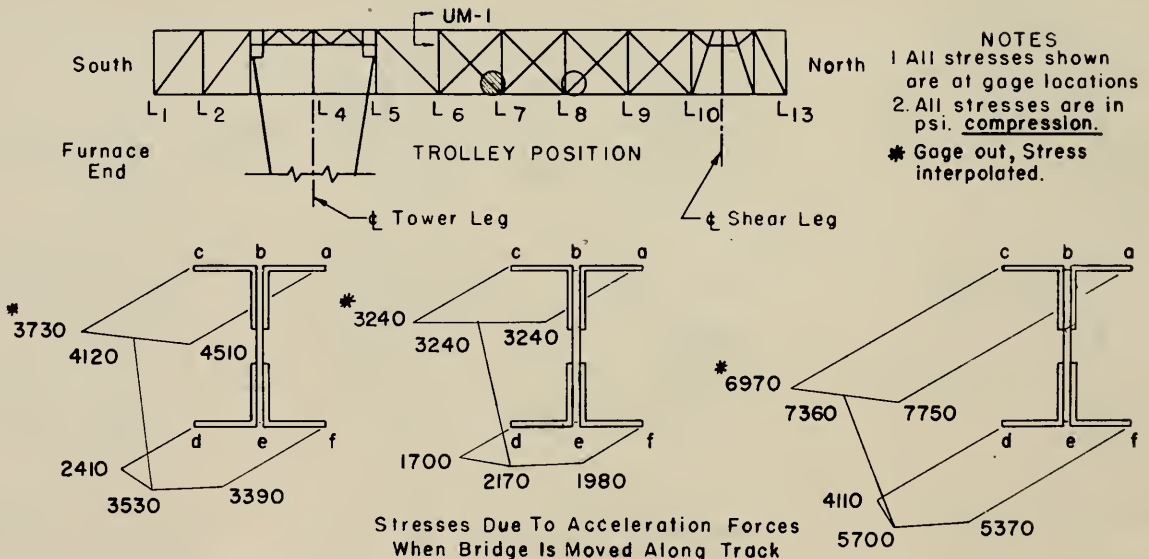
Location Of Trolley (1st. Wheel)
6' from L1 foward L2 — Static ——— at L6
In panel 2-3 – – – Dynamic — about 15' south of L6.

Measured Total Live Load In Member
162,400 lb. T. ——— Static ——— 177,000 lb.C.
132,600 lb. T. – – – Dynamic ——— 164,800 lb.C.

Maximum Stress Range
4,410 psi. Tens. ——— Gage b ——— 6,000 psi. Comp.

SEC. UM-1 SPAN SKEWED EAST





Section UM-1

4 L's 6x6x5/8

PL 15x5/8

COMBINED DYNAMIC STRESS
SECTION UM-1
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock; Penn. June, July, 1953

FIG. 33

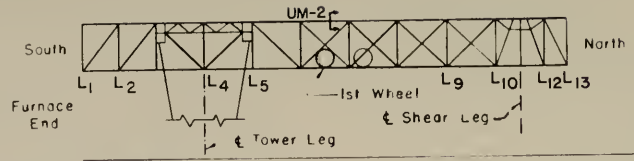
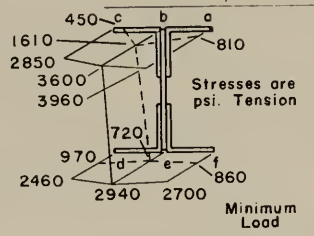


FIG. 34

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses - - - -
4. Scale: 1inch = 3000 psi

SUMMARY OF MEASURED STRESSES
SECTION UM-2
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

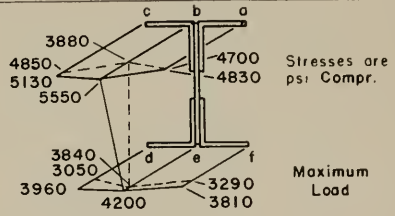


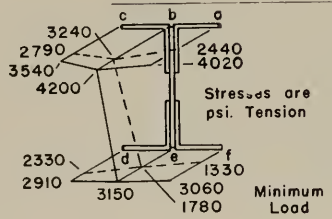
Location Of Trolley (1st. Wheel)
6' North of L1 ———— Static ———————— at L6
Mid Point Panel 2-3 - - Dynamic - - - - 5' North of L6

Measured Total Live Load in Member
116,613 lb. T. ———— Static ——— 173,124 lb. C.
28,463 lb. T. ———— Dynamic ——— 148,743 lb. C.

Maximum Stress Range
3,600 psi. Tens. ——— Gage b - - 5,550 psi. Compr.

SEC. UM-2 SPAN SKEWED WEST



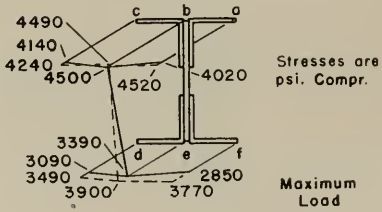


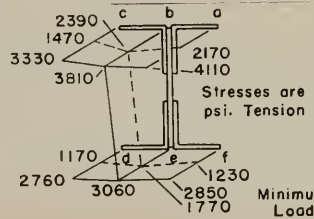
Location Of Trolley (1st. Wheel)
6' North of L1 ———— Static ———————— at L6
Mid Point Panel 2-3 — Dynamic ——————— at L6

Measured Total Live Load in Member
131,544 lb. T. ———— Static ——— 138,537 lb. C.
87,620 lb. T. ———— Dynamic ——— 153,770 lb. C.

Maximum Stress Range
4,200 psi. Tens. ——— Gage b - - 4,500 psi. Compr.

SEC. UM-2 SPAN SQUARE



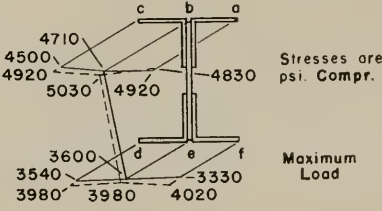


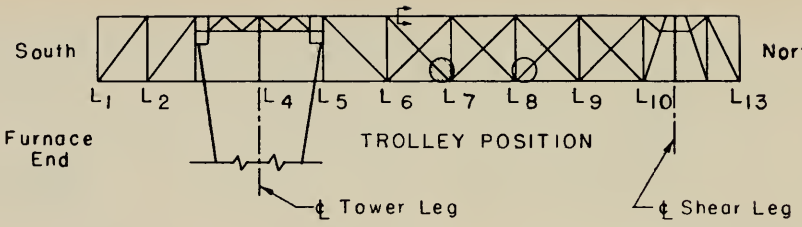
Location Of Trolley (1st. Wheel)
6' North of L1 ———— Static ———————— at L6
5' South of L3 ———— Dynamic ———————— at L6

Measured Total Live Load in Member
125,496 lb. T. ———— Static ——— 154,980 lb. C.
64,260 lb. T. ———— Dynamic ——— 168,588 lb. C.

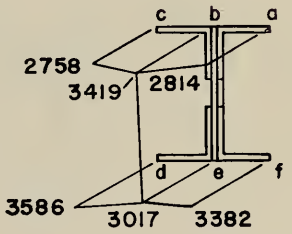
Maximum Stress Range
4,110 psi. Tens. ——— Gage a - - 4,920 psi. Compr.

SEC. UM-2 SPAN SKEWED EAST

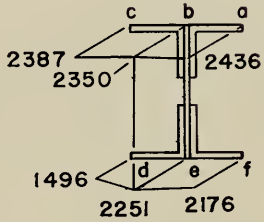




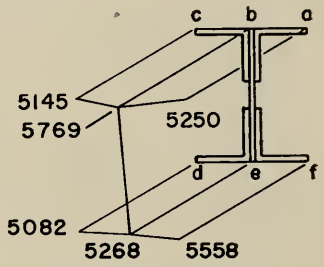
NOTES
1 All stresses shown are at gage locations
2 All stresses are in psi. compression.
3. Scale: 1 in. = 3000 psi



Dynamic Stress
1st. Wheel of Trolley At L_7
(Run D-6B)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-6D)



Total Combined Stress

Section UM-2

4 Ls 6 x 6 x 5/8

Pl 15 x 5/8

COMBINED DYNAMIC STRESS
SECTION UM-2
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG 35

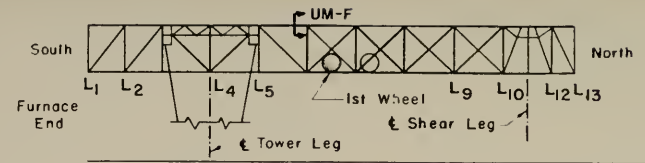
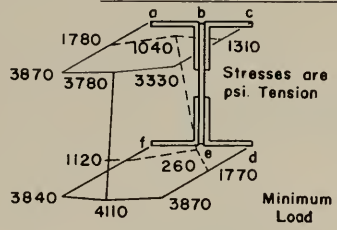


FIG. 36

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses - - - -
4. Scale: 1 inch = 3000 psi

SUMMARY OF MEASURED STRESSES
SECTION UM-F
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

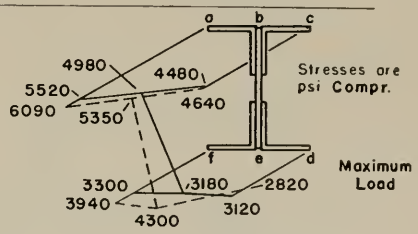


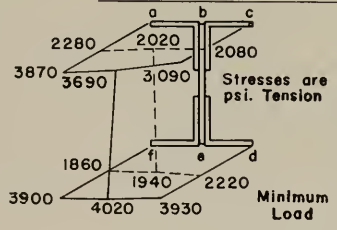
Location Of Trolley (1st. Wheel)
6' From L1 Toward L2 — Static — — — — — — — — at L6
In Panel 2-3 — — — — — Dynamic — About 7' South of L6

Measured Total Live Load in Member
143,800 lb. T. — — — — Static — — — — 155,000 lb. C.
46,000 lb. T. — — — — Dynamic — — — — 171,100 lb. C.

Maximum Stress Range
3,870 psi. Tens. — — — Gage a — — — 5,520 psi. Compr.

SEC. UM-F SPAN SKEWED WEST



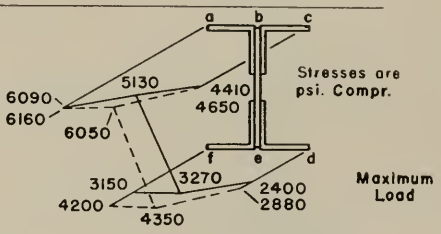


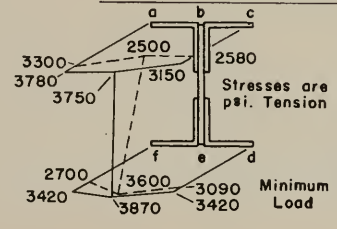
Location Of Trolley (1st. Wheel)
6' From L1 Toward L2 — Static — — — — — — — — at L6
In Panel 2-3 — — — — — Dynamic — About 7' South of L6

Measured Total Live Load in Member
142,000 lb. T. — — — — Static — — — — 154,100 lb. C.
78,200 lb. T. — — — — Dynamic — — — — 178,500 lb. C.

Maximum Stress Range
3,870 psi. Tens. — — — — Gage a — — — 6,090 psi. Compr.

SEC. UM-F SPAN SQUARE



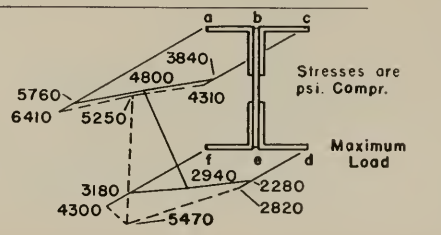


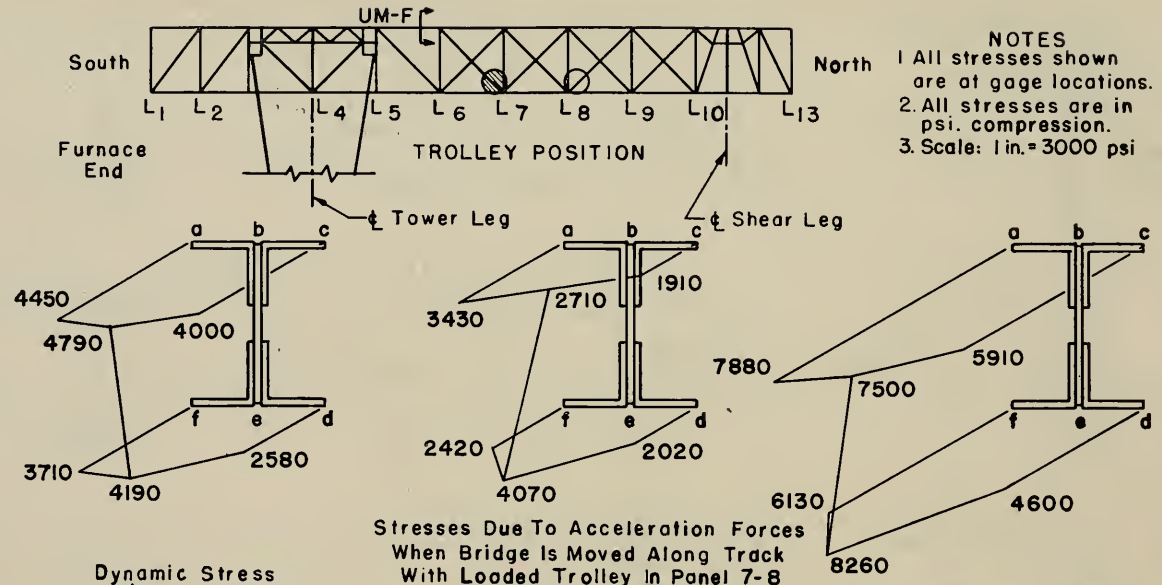
Location Of Trolley (1st. Wheel)
6' From L1 Toward L2 — Static — — — — — — — — at L6
In Panel 2-3 — — — — — Dynamic — About 15' South of L6

Measured Total Live Load In Member
135,000 lb. T. — — — — Static — — — — 143,800 lb. C
112,000 lb. T. — — — — Dynamic — — — — 180,000 lb. C.

Maximum Stress Range
3,780 psi. Tens. — — — — Gage a — — — 5,760 psi. Compr.

SEC. UM-F SPAN SKEWED EAST





Section UM-F

4 ls 6 x 6 x 5/8

R. 15 x 5/8

COMBINED DYNAMIC STRESS
SECTION UM-F
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 37

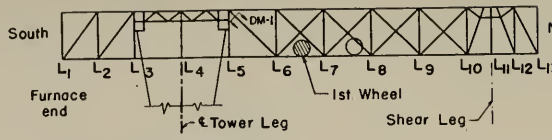
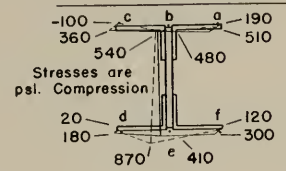


FIG. 38

NOTES
1. All stresses shown are at gage locations.
2. Static Stresses ——
3. Dynamic Stresses – – –

Summary Of Measured Stresses
SECTION DM-1
Ore Bridge No. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June July 1953



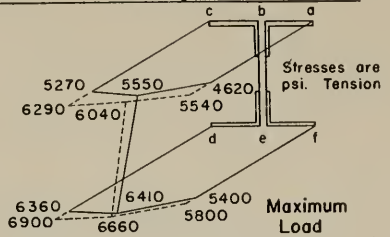
Minimum Load

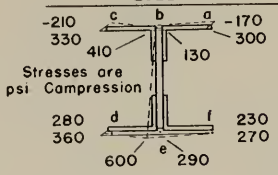
Location Of Trolley (1st. Wheel)
Mid point panel 3-4 – – – Static – – – – – – – – – at L6
About 3' north of L3 – – Dynamic – about 3' south of L6

Measured Total Live Load in Member
7410 lb. c. – – – – – – Static – – – – – 108,340 lb. T.
10,760 lb. c. – – – – – – Dynamic – – – 116,250 lb. T.

Maximum Stress Range
870 psi. Compr. – – – – Gage e – – – 6,600 psi. Tens.

SEC. DM-1 SPAN SKEWED WEST





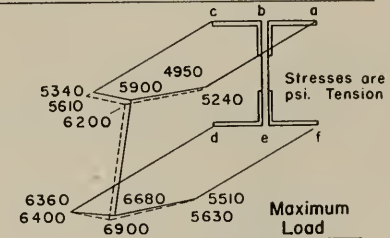
Minimum Load

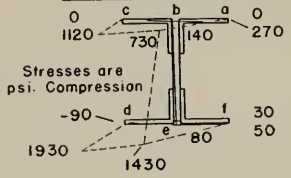
Location Of Trolley (1st. Wheel)
Mid point panel 3-4 – – Static – – – – – – – – at L6
At L3 – – – – – – – Dynamic – – about 3' south of L6

Measured Total Live Load in Member
5610 lb. c. – – – – – – Static – – – – 113,450 lb. T.
6300 lb. c. – – – – – – Dynamic – – – 117,990 lb. T.

Maximum Stress Range
600 psi. Compr. – – – – Gage e – – – 6,900 psi. Tens.

SEC. DM-1 SPAN SQUARE





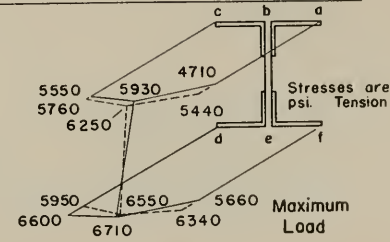
Minimum Load

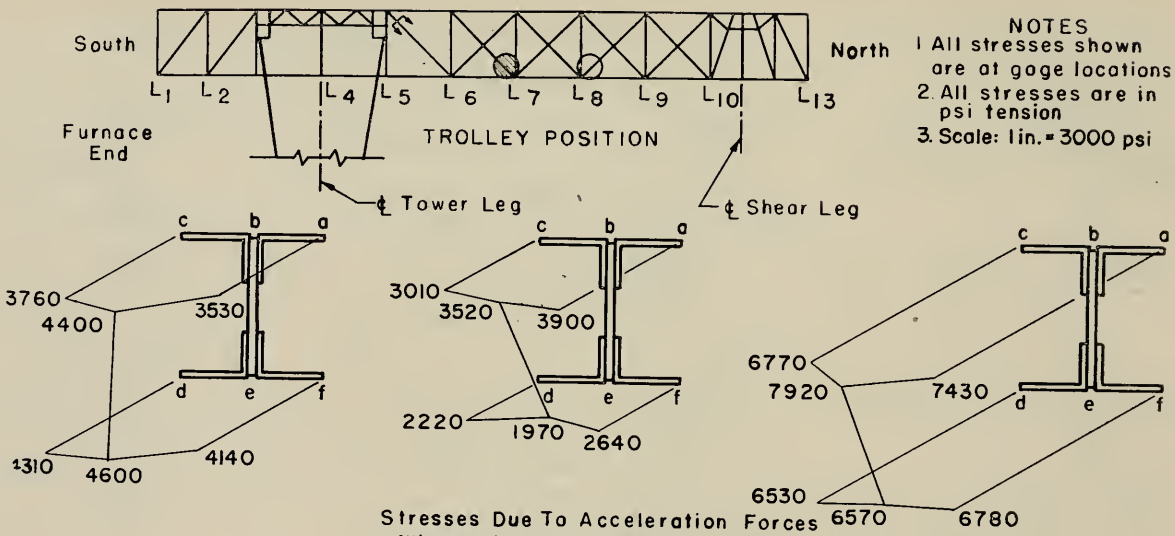
Location Of Trolley (1st. Wheel)
Mid point panel 3-4 – – Static – – – – – – – – at L6
About 3' north of L3 – – Dynamic — about 7' south of L6

Measured Total Live Load in Member
1850 lb. c. – – – – – – Static – – – – 114,150 lb. T.
18,830 lb. c. – – – – Dynamic – – – 117,300 lb. T.

Maximum Stress Range
1,930 psi. Compr. – – – Gage d – – – 6,600 psi. Tens.

SEC. DM-1 SPAN SKEWED EAST





Section DM-1

$4 \angle s\ 5 \times 3\frac{1}{2} \times \frac{3}{8}$

$PL\ 10 \times \frac{5}{8}$

COMBINED DYNAMIC STRESS
SECTION DM-1
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 39

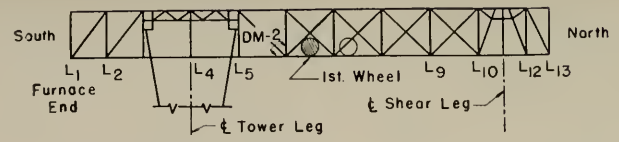
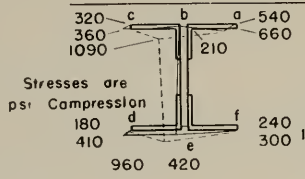


FIG. 40

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses – – – –

SUMMARY OF MEASURED STRESSES
SECTION DM-2
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock Penna.
June, July, 1953



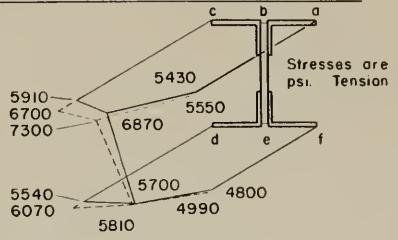
Min. Location Of Trolley (1st. Wheel) Max.
Mid Point Panel 3-4 — — — Static — — — — — — — — — at L6
About 3' North of L3 — — — Dynamic — — — about 3' South of L6

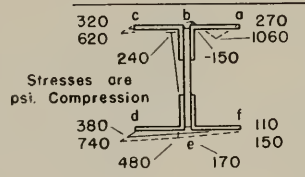
Measured Total Live Load in Member

6060 lb. C.	Static	112,900 lb. T.
16,620 lb. C.	Dynamic	118,300 lb. T.

Maximum Stress Range
1,090 psi. Compr. — — — — Gage b — — — — — 7,300 psi. Tens.

SEC. DM-2 SPAN SKEWED WEST





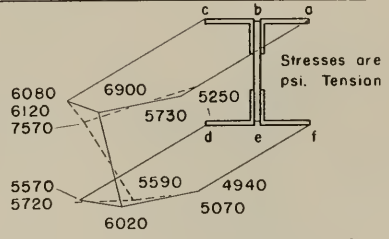
Min. Location Of Trolley (1st. Wheel) Max.
Mid Point Panel 3-4 — — — Static — — — — — — — — — at L6
About 3' North of L3 — — — Dynamic — — — about 3' South of L6

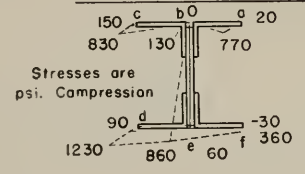
Measured Total Live Load in Member

4010 lb. C.	Static	116,250 lb. T.
4700 lb. C.	Dynamic	117,600 lb. T.

Maximum Stress Range
150 psi. Tens. — — — — Gage b — — — — — 7,570 psi. Tens.

SEC. DM-2 SPAN SQUARE





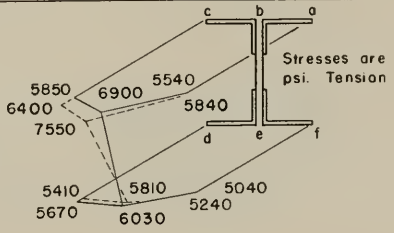
Min. Location Of Trolley (1st. Wheel) Max.
Mid Point Panel 3-4 — — — Static — — — — — — — — — at L6
About 3' North of L3 — — — Dynamic — — — about 7' South of L6

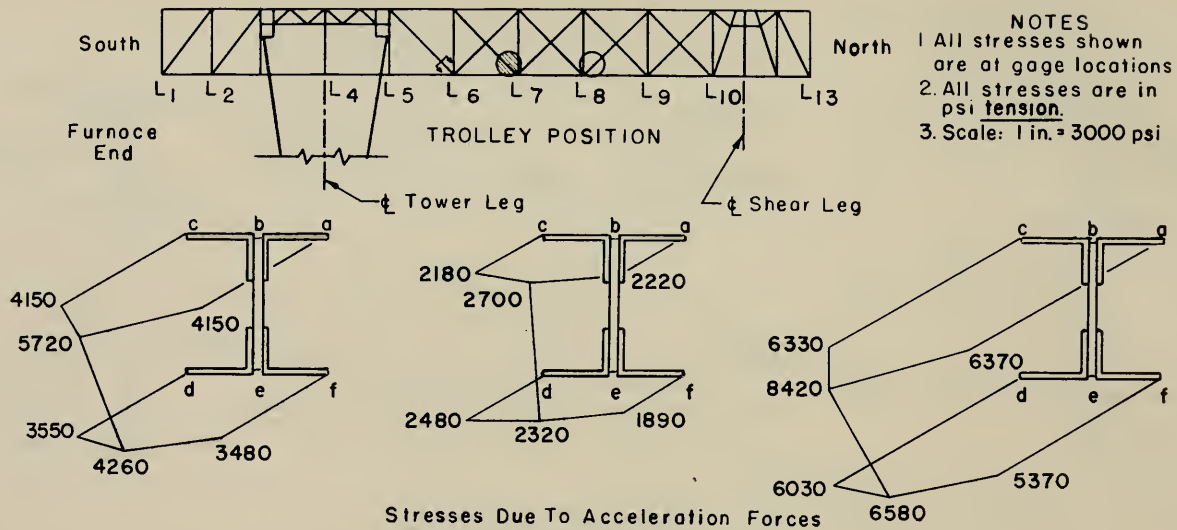
Measured Total Live Load in Member

1620 lb. C.	Static	116,000 lb. T.
9210 lb. C.	Dynamic	120,000 lb. T.

Maximum Stress Range
130 psi. Compr. — — — — Gage b — — — — — 7,550 psi. Tens.

SEC. DM-2 SPAN SKEWED EAST





Dynamic Stress
1 st. Wheel of Trolley At L_7
(Run D-1B)

Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-1D)

Total Combined Stress

Section DM-2

4 ∟ 5 x $3\frac{1}{2}$ x $\frac{3}{8}$

PL 10 x $\frac{5}{8}$

COMBINED DYNAMIC STRESS
SECTION DM-2
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 41

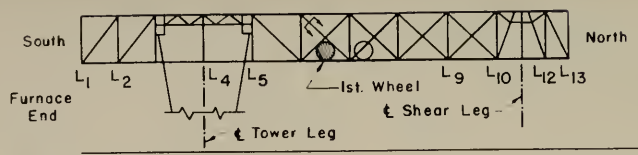
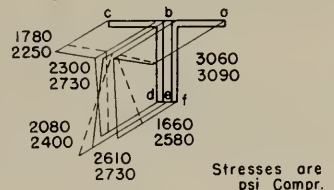


FIG. 42

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses – – – –
4. Scale: 1 inch = 3000 psi

SUMMARY OF MEASURED STRESSES
SECTION DM-3
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

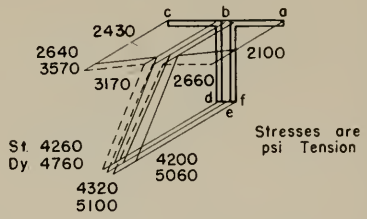


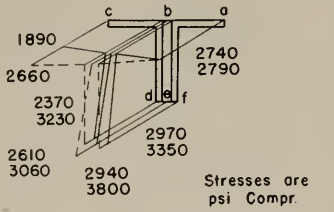
Min. Location Of Trolley (1st. Wheel) Max.
Mid Point Panel 4-5 – – – – Static – – – – – – – – – – – – – – – – at L_7
About 5' South of L_5 – – – Dynamic – – – – – About 5' North of L_7

Measured Total Live Load in Member
28,750 lbs. C – – – – – – – Static – – – – – – – – – – 34,410 lbs. T
25,610 lbs. C – – – – – – – Dynamic – – – – – – – – – 42,110 lbs. T

Maximum Stress Range
2730 psi Compr. – – – – – – Gage e – – – – – – – – – 5,100 psi Tens.

SEC. DM-3 SPAN SKEWED WEST



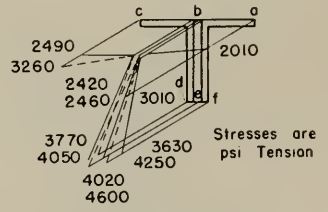


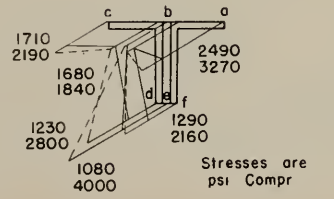
Min. Location Of Trolley (1st. Wheel) Max.
Mid Point Panel 4-5 – – – – Static – – – – – – – – – – – – – – – – at L_7
About 5' South of L_5 – – – Dynamic – – – – – About 5' North of L_7

Measured Total Live Load in Member
27,930 lbs. C – – – – – – Static – – – – – – – – – 32,200 lbs. T
35,760 lbs. C – – – – – – Dynamic – – – – – – – – – 35,730 lbs. T

Maximum Stress Range
3,800 psi Compr. – – – – – Gage e – – – – – – – – – 4,600 psi Tens.

SEC. DM-3 SPAN SQUARE



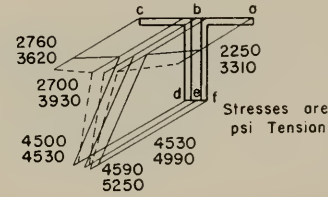


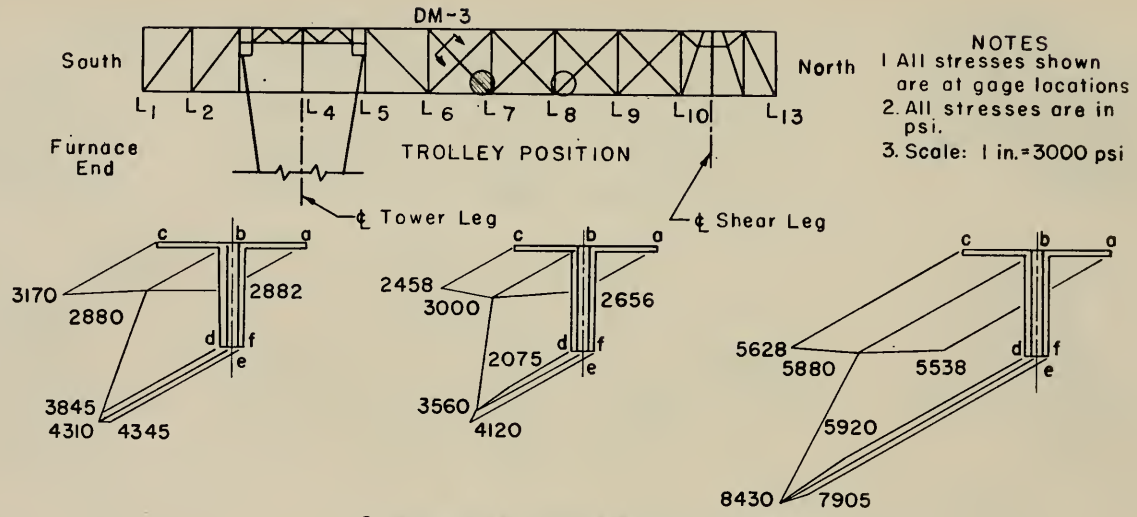
Min. Location Of Trolley (1st. Wheel) Max.
Mid Point Panel 4-5 – – – – Static – – – – – – – – – – – – – – – – at L_7
About 5' South of L_5 – – – Dynamic – – – – – About 5' North of L_7

Measured Total Live Load in Member
16,950 lbs. C – – – – – – – Static – – – – – – – – – 38,260 lbs. T
26,880 lbs. C – – – – – – – Dynamic – – – – – – – – – 45,850 lbs T

Maximum Stress Range
1,080 psi Compr. – – – – – Gage e – – – – – – – – – 5,250 psi Tens.

SEC. DM-3 SPAN SKEWED EAST





Section DM-3

2 ⌊s 6 x 4 x 3/8

PL 6 x 5/8

COMBINED DYNAMIC STRESS
SECTION DM-3
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 3
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 43

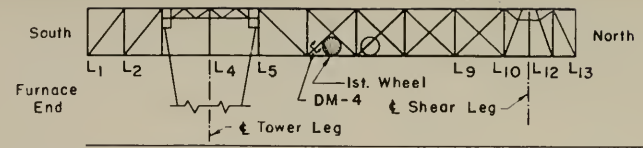
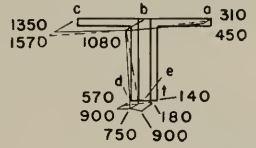


FIG. 44

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses – – – –
4. Scale: 1 inch = 3000 psi

SUMMARY OF MEASURED STRESSES
SECTION DM-4
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953



Stresses are psi. Tension

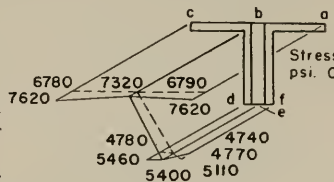
Minimum Load

Location Of Trolley (1st. Wheel)
Mid Point Panel 4-5 ——— Static ——— at L_7
Mid Point Panel 4-5 – – – – Dynamic – – – – Mid Point Panel 6-7

Measured Total Live Load in Member
7150 lbs. T. ——— Static ——— 49,050 lbs C.
5760 lbs. T. – – – – Dynamic – – – – 45,350 lbs C.

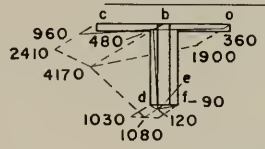
Maximum Stress Range
1350 psi. T. ——— Gage c ——— 7620 psi. C.

SEC. DM-4 SPAN SKEWED WEST



Stresses are psi. Compr.

Maximum Load



Stresses are psi. Tension

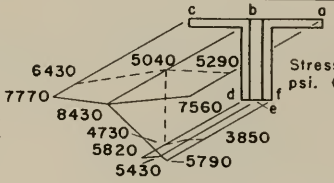
Minimum Load

Location Of Trolley (1st. Wheel)
Mid Point Panel 4-5 ——— Static ——— at L_7
Mid Point Panel 4-5 – – – – Dynamic – – – – at L_7

Measured Total Live Load in Member
2470 lbs. T. ——— Static ——— 54,580 lbs. C.
20,600 lbs. T. – – – – Dynamic – – – – 35,970 lbs. C.

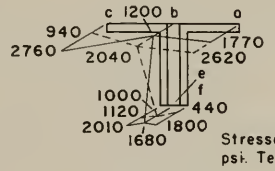
Maximum Stress Range
4170 lbs. T. ——— Gage b ——— 5090 psi. C.

SEC. DM-4 SPAN SQUARE



Stresses are psi. Compr.

Maximum Load



Stresses are psi. Tension

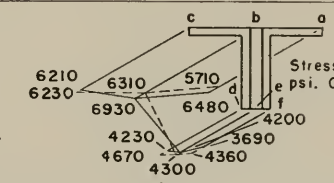
Minimum Load

Location Of Trolley (1st. Wheel)
Mid Point Panel 4-5 ——— Static ——— at L_7
Mid Point Panel 4-5 – – – Dynamic ——— 5' South of L_7

Measured Total Live Load In Member
11,730 lbs. T. ——— Static ——— 44,200 lbs. C.
11,700 lbs. T. – – – – Dynamic – – – – 41,630 lbs. C.

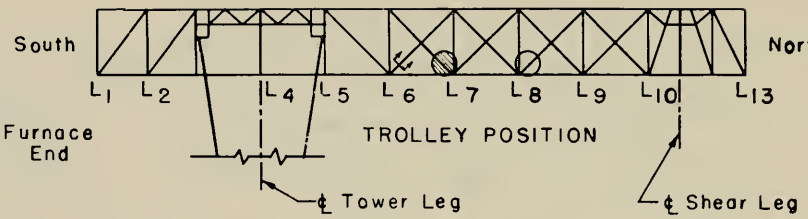
Maximum Stress Range
2760 psi. T ——— Gage c ——— 6210 psi. C.

SEC. DM-4 SPAN SKEWED EAST

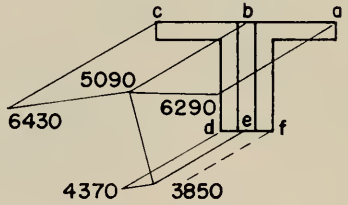


Stresses are psi. Compr.

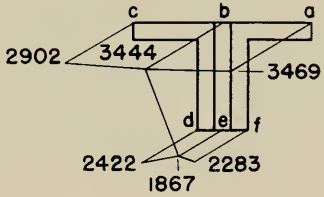
Maximum Load



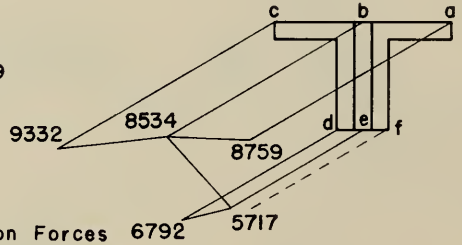
NOTES
1. All stresses shown are at gage locations.
2. All stresses are in psi Compression.
3. Scale: 1 in. = 3000 psi



Dynamic Stress
1st. Wheel of Trolley At L_7
(Run D-5B)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-5D)



Total Combined Stress

Section DM-4

2 ⌊s 4x3x3/8

PL 4x5/8

COMBINED DYNAMIC STRESS
SECTION DM-4
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 45

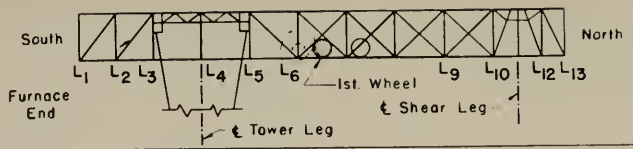
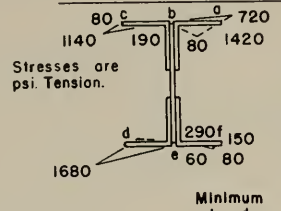


FIG. 46

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses - - - -
4. Scale: 1 inch = 3000 psi.

SUMMARY OF MEASURED STRESSES
SECTION VM-1
ORE BRIDGE NO 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

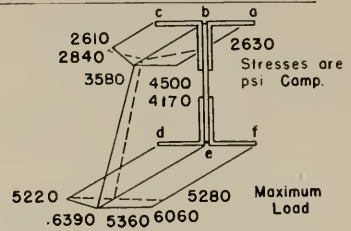


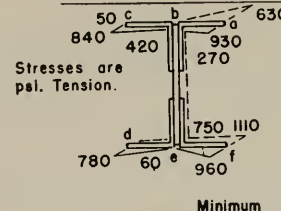
Location Of Trolley (1st. Wheel)
Mid Point Panel 3-4 ——— Static ——— at L6
5' North of L3 ——— Dynamic ——— at L6

Measured Total Live Load in Member
5328 lb. T. ——— Static ——— 85,860 lb. C.
4382 lb. T. ——— Dynamic ——— 73,050 lb. C.

Maximum Stress Range
1680 psi. Tens. ——— Gage d ——— 5220 psi. C.

SEC. VM-1 SPAN SKEWED WEST



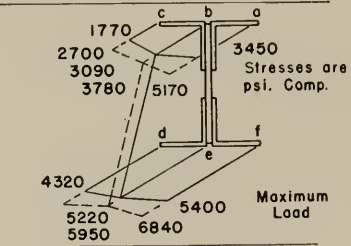


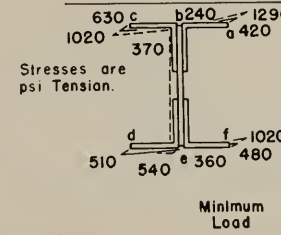
Location Of Trolley (1st. Wheel)
Mid Point Panel 3-4 ——— Static ——— at L6
5' North of L3 ——— Dynamic ——— 5' South of L6

Measured Total Live Load in Member
11039 lb. T. ——— Static ——— 67,950 lb. C.
12317 lb. C ——— Dynamic ——— 81,880 lb. C.

Maximum Stress Range
960 psi. Tens. ——— Gage f ——— 5400 psi C.

SEC. VM-1 SPAN SQUARE



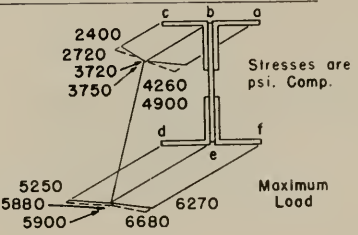


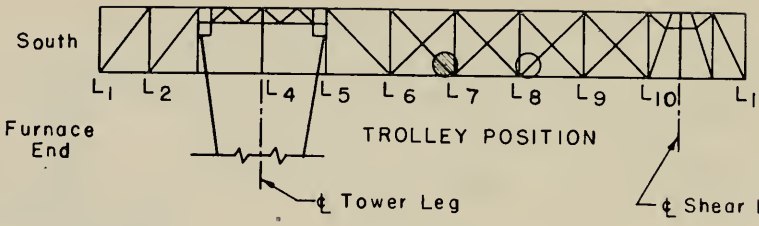
Location Of Trolley (1st. Wheel)
Mid Point Panel 3-4 ——— Static ——— at L6
At L3 ——— Dynamic ——— 5' South of L6

Measured Total Live Load in Member
2324 lb. T. ——— Static ——— 79,400 lb. C.
359 lb. T. ——— Dynamic ——— 80,300 lb. C.

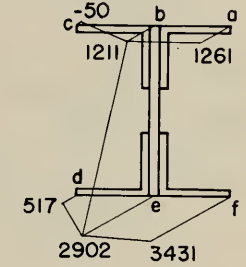
Maximum Stress Range
540 psi. Tens. ——— Gage e ——— 5900 psi. C.

SEC. VM-1 SPAN SKEWED EAST

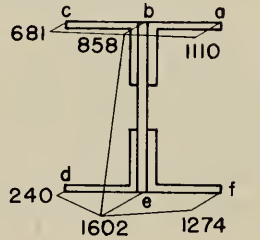




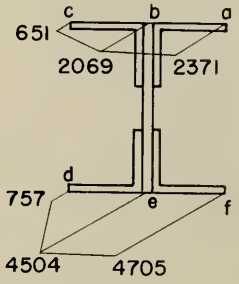
NOTES
1. All stresses shown are at gage locations
2. All stresses are in psi compression.
3. Scale: 1 in. = 3000 psi



Dynamic Stress
1st. Wheel of Trolley At L7
(Run D-6B)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-6D)



Total Combined Stress

Section VM-1

4 Ls 4 x 3 1/2 x 3/8

Pl 9 1/2 x 5/8

COMBINED DYNAMIC STRESS
SECTION VM-1
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 47

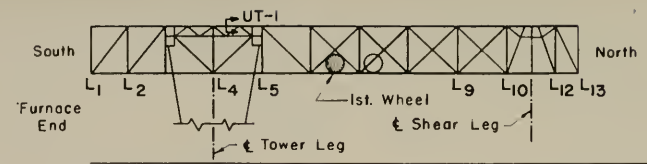
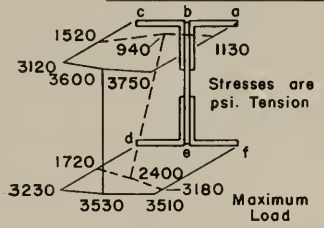


FIG. 48

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses – – – –
4. Scale: 1 inch = 3000 psi

SUMMARY OF MEASURED STRESSES
SECTION UT-1
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

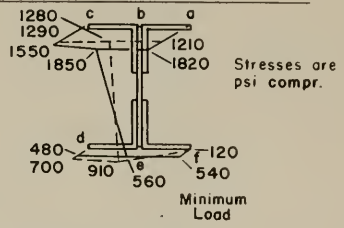


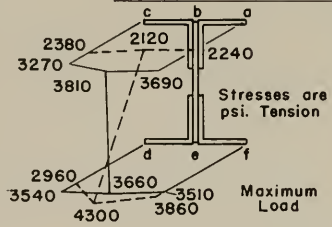
Location Of Trolley (1st. Wheel)
In Panel 1-2, Near L1 – – Static – – – – – – – – – at L4
In Panel 2-3 – – – – – – Dynamic – – About 1' North of L4

Measured Total Live Load in Member
130,800 lb. T. – – – – – – Static – – – – – – 42,900 lb. C.
68,750 lb. T. – – – – – – Dynamic – – – – – – 34,700 lb. C.

Maximum Stress Range
3,750 psi. Tens. – – – – – – Gage a – – – – 1,820 psi. Compr.

SEC. UT-1 SPAN SKEWED WEST



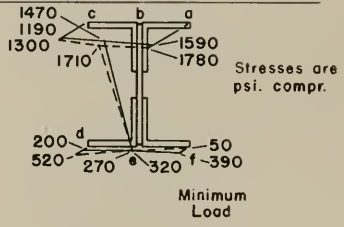


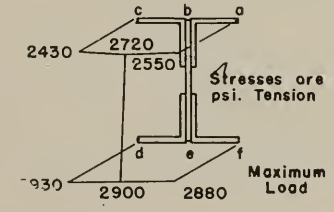
Location Of Trolley (1st. Wheel)
In Panel 1-2, Near L1 – – Static – – – – – – – – – at L4
In Panel 2-3 – – – – – – Dynamic – – About 1' North of L4

Measured Total Live Load in Member
135,500 lb. T. – – – – – – Static – – – – – – 32,500 lb. C.
112,500 lb T. – – – – – Dynamic – – – – – – 35,450 lb. C.

Maximum Stress Range
3,690 psi. Tens. – – – – Gage a – – – 1,590 psi. Compr.

SEC. UT-1 SPAN SQUARE



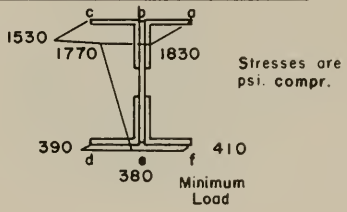


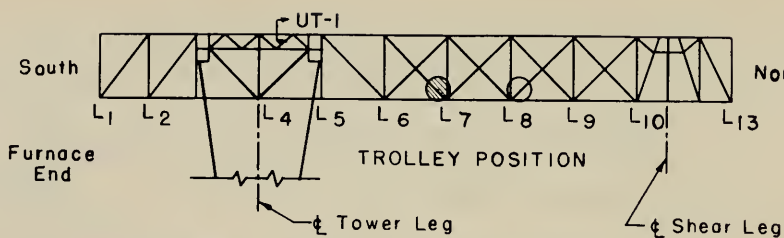
Location Of Trolley (1st. Wheel)
5' Toward L1 From L2 – – Static – – – – – – – – – at L4
Dynamic

Measured Total Live Load In Member
103,500 lb. T. – – – – – – Static – – – – – 39,850 lb. C.
Dynamic

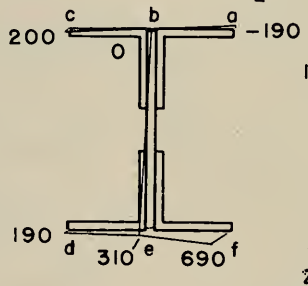
Maximum Stress Range
2,720 psi. Tens. – – – – Gage b – – – 1,770 psi. Compr.

SEC. UT-1 SPAN SKEWED EAST

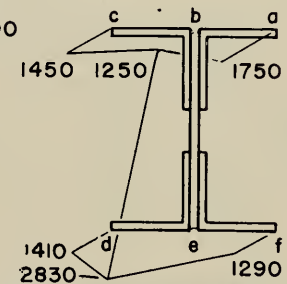




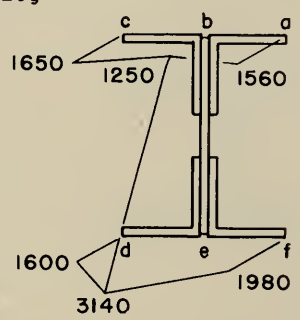
NOTES
1 All stresses shown are at gage locations
2 All stresses are in psi. tension.
3. Scale: 1 in. = 3000 psi



Dynamic Stress
1st. Wheel of Trolley At L_7
(Run D-4B)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-4D)



Total Combined Stress

Section UT-1

4 Ls 6x6x5/8

PL 15x5/8

COMBINED DYNAMIC STRESS
SECTION UT-1
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 49

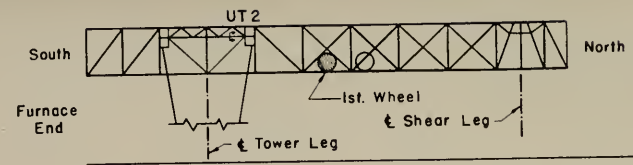
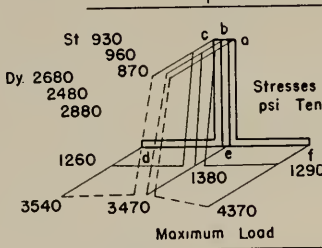


FIG. 50

NOTES
1. All stresses shown are at gage locations
2. Static Stresses ———
3. Dynamic Stresses – – – –
4. Scale: 1 inch = 3000 psi

SUMMARY OF MEASURED STRESSES
SECTION UT 2
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

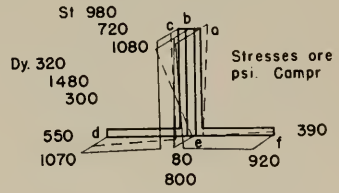


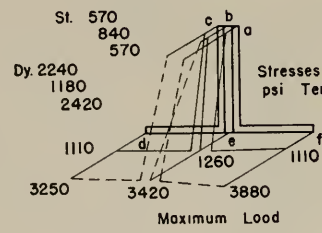
Location Of Trolley (1st. Wheel)
In Panel 1-2 near L_1 – Static – – At Midpoint of Panel 5-6
In Panel 2-3 – – – – Dynamic – – – About 3' South of L_5

Measured Total Live Load in Member
20,600 lb. T. – – – – Static – – – – – – – – 17,180 lb. C.
59,800 lb. T. – – – – Dynomic – – – – – – – – 5,360 lb. C.

Maximum Stress Range
3,540 psi Tens. – – – Gage d – – – – – – 550 psi Comp.

SEC. UT 2 SPAN SKEWED WEST



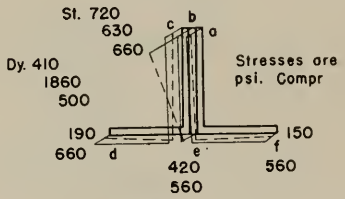


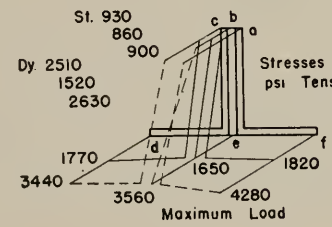
Location Of Trolley (1st. Wheel)
In Panel 1-2 near L_1 – Static – – At Midpoint of Panel 5-6
In Panel 2-3 – – – – Dynamic – – – About 1' South of L_5

Measured Total Live Load in Member
16,820 lb T. – – – – Static – – – – – – – – 11,700 lb. C.
50,200 lb. T. – – – – Dynamic – – – – – – – – 10,890 lb. C.

Maximum Stress Range
3,880 psi Tens – – – Goge f – – – – – – – – 150 psi Comp.

SEC. UT 2 SPAN SQUARE



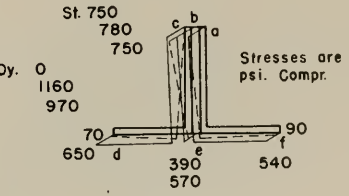


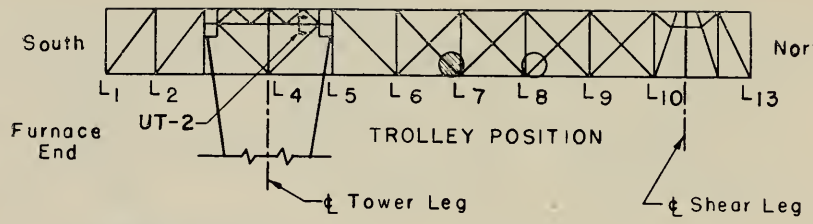
Location Of Trolley (1st. Wheel)
In Panel 1-2, 5' from L_1 – Static – – At Midpoint of Panel 5-6
In Panel 2-3 – – – – Dynamic – – – About 1' South of L_5

Measured Total Live Load In Member
24,450 lb T – – – – Static – – – – – – – – 12,450 lb. C.
55,300 lb. T. – – – – Dynamic – – – – – – – – 9,920 lb. C.

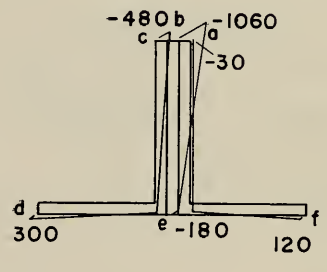
Maximum Stress Range
4,280 psi Tens. – – – Gage f – – – – – – – – 90 psi Comp.

SEC. UT 2 SPAN SKEWED EAST

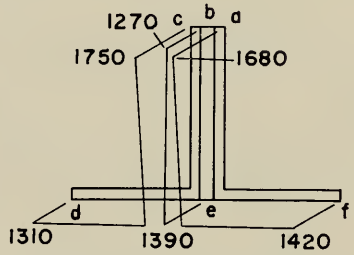




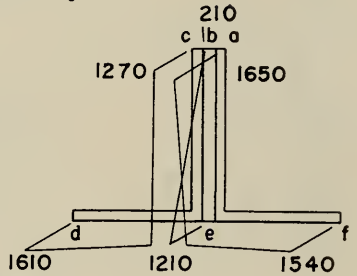
NOTES
1 All stresses shown are at gage locations
2 All stresses are in psi tension (- compression)
3. Scale: 1 in. = 3000 psi.



Dynamic Stress
1 st. Wheel of Trolley At
(Run D-4B)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-4D)



Total Combined Stress

Section UT-2
4L 8x6x1/2
PL 8 x 5/8

COMBINED DYNAMIC STRESS
SECTION UT-2
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 51

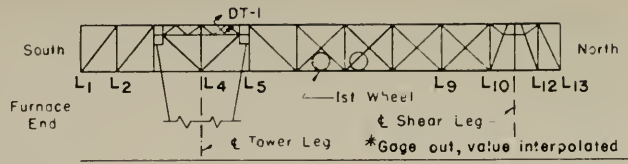


FIG. 52

NOTES
Scale 1 inch = 3000 psi
1 All stresses shown are at gage locations
2 Static Stresses ———
3 Dynamic Stresses – – –
4 Skew East, most reliable result.

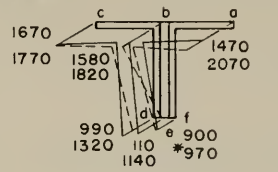
SUMMARY OF MEASURED STRESSES
SECTION DT-1
ORE BRIDGE NO 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

Location Of Trolley (1st. Wheel)
Static _ _ _ _ _ _ _ _ _ at L4
Dynamic _ _ About 7' South of L4

Measured Total Live Load in Member
Static _ _ _ _ _ 15,420 lb C
Dynamic _ _ _ _ _ 15,450 lb C

Maximum Stress Range
Gage a _ _ _ 2,070 psi. Compr

SEC. DT-1 SPAN SKEWED WEST



Stresses cre psi Compr

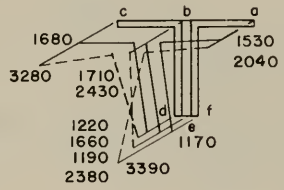
Maximum Load

Location Of Trolley (1st. Wheel)
Static _ _ _ _ _ _ _ _ _ at L4
Dynamic _ About 7' South of L4

Measured Total Live Load in Member
Static _ _ _ _ _ _ 16,490 lb C
Dynamic _ _ _ _ _ _ 27,120 lb C

Maximum Stress Range
Gage c _ _ _ _ 3,280 psi. Compr.

SEC. DT-1 SPAN SQUARE



Stresses are psi. Compr.

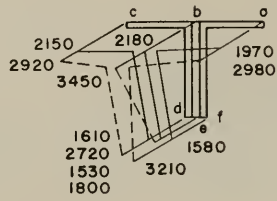
Maximum Load

Location Of Trolley (1st. Wheel)
Static _ _ _ _ _ _ _ _ _ at L4
Dynamic _ About 7' South of L4

Measured Total Live Load In Member
Static _ _ _ _ _ 21,110 lb. C.
Dynamic _ _ _ _ _ 33,550 lb. C.

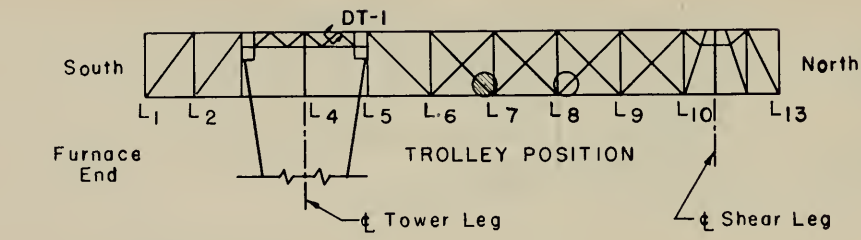
Maximum Stress Range
Gage b _ _ 3,450 psi. Compr.

SEC. DT-1 SPAN SKEWED EAST

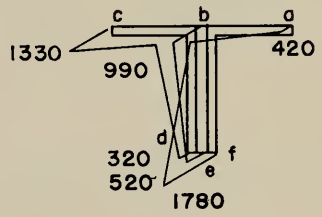


Stresses are psi. Compr

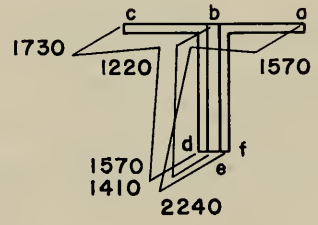
Maximum Load



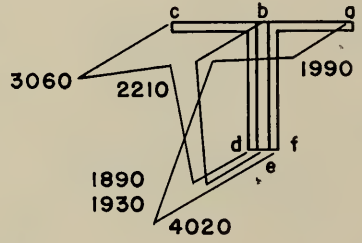
NOTES
1. All stresses shown are at gage locations
2. All stresses are in psi. compression.
3. Scale: 1 in. = 3000 psi



Dynamic Stress
1st. Wheel of Trolley At L_7
(Run D-38)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-3D)



Total Combined Stress

Section DT-1

$2\angle\ 6\times4\times\frac{3}{8}$

PL $6\times\frac{5}{8}$

COMBINED DYNAMIC STRESS
SECTION DT-1
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 53

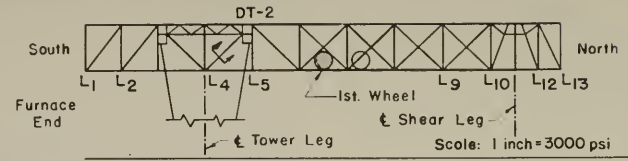
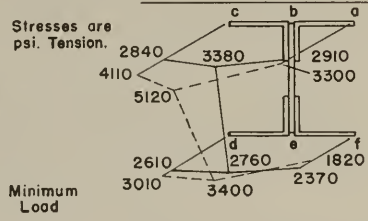


FIG. 54

NOTES

1. All stresses shown are at gage locations
2. Stotic Stresses ———
3. Dynamic Stresses – – –
* Gage out, value interpolated.

SUMMARY OF MEASURED STRESSES
SECTION DT-2
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

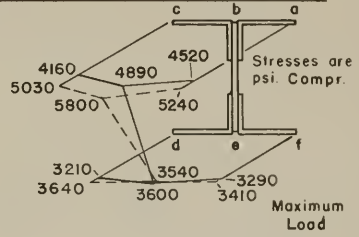


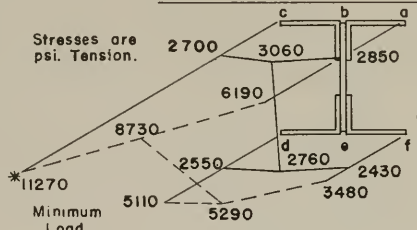
Location Of Trolley (1st. Wheel)
In Panel 1-2 Near L1 – – Static – – – – – – – – – – – – at L5
In Panel 2-3 – – – – – – Dynamic – – About 3' South of L5

Measured Total Live Load in Member
63,750 lb. T. – – – – – Stotic – – – – – – 88,550 lb. C.
85,800 lb. T. – – – – – Dynamic – – – – – – 98,000 lb. C.

Maximum Stress Range
5,120 psi. Tens. – – – – Gage b – – – 5,800 psi. Compr.

SEC. DT-2 SPAN SKEWED WEST



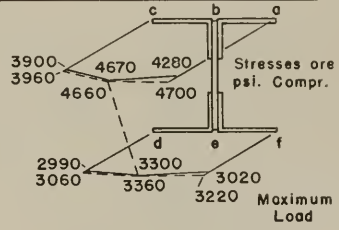


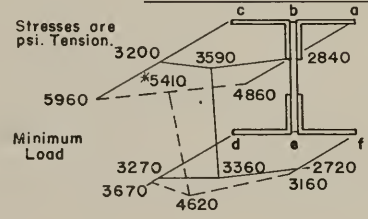
Location Of Trolley (1st. Wheel)
In Panel 1-2 Near L1 – – Static – – – – – – – – – – – at L5
In Panel 2-3 – – – – – – Dynamic – – About 3' South of L5

Measured Total Live Load in Member
60,850 lb. T. – – – – – Stotic – – – – – – 83,100 lb. C.
147,400 lb. T. – – – – – Dynamic – – – – – 84,300 lb. C.

Maximum Stress Range
11,270 psi. Tens. – – – Gage c – – – – 3,960 psi. Compr.

SEC. DT-2 SPAN SQUARE



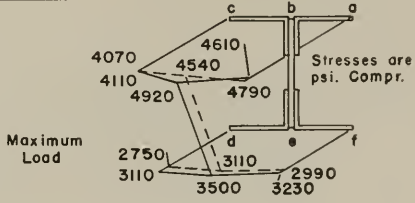


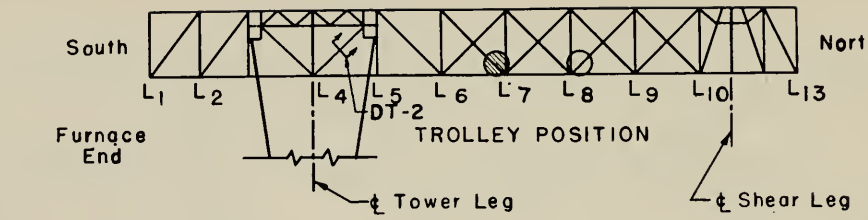
Location Of Trolley (1st. Wheel)
In Panel 1-2, 5' From L1 – Static – – – – – – – – – – at L5
In Panel 2-3 – – – – – – Dynamic – – – About 1' North of L5

Measured Total Live Load In Member
72,100 lb. T. – – – – – Static – – – – – – 87,850 lb. C.
104,350 lb. T. – – – – – Dynamic – – – – – 80,700 lb. C.

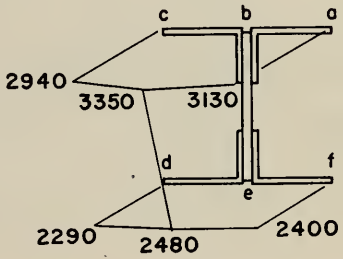
Maximum Stress Range
5,960 psi. Tens. – – – Gage c – – – – 4,110 psi. Compr.

SEC. DT-2 SPAN SKEWED EAST

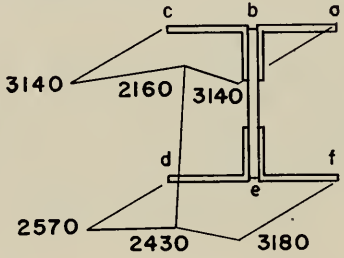




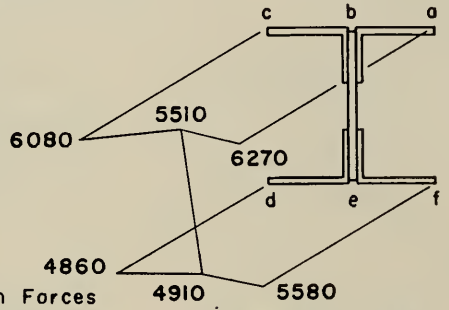
NOTES
1. All stresses shown are at gage locations
2. All stresses are in psi compression
3. Scale: 1 in.=3000 psi



Dynamic Stress
1st. Wheel of Trolley At L_7
(Run D-3B)



Stresses Due To Acceleration Forces
When Bridge Is Moved Along Track
With Loaded Trolley In Panel 7-8
(Run D-3D)



Total Combined Stress

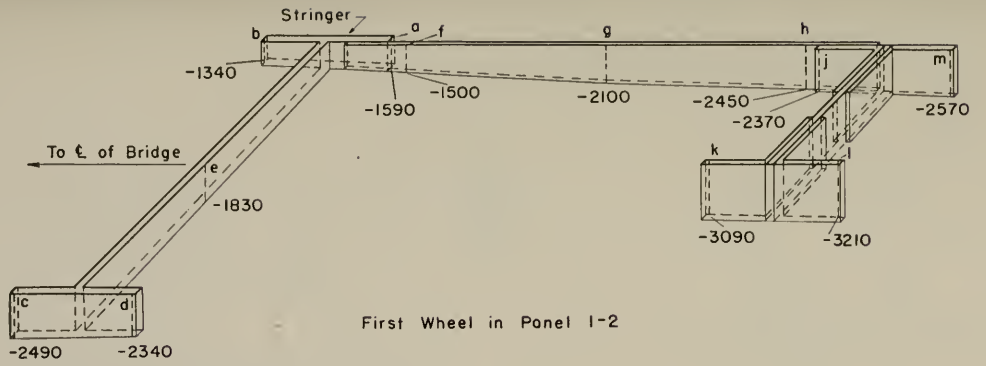
Section DT-2

4L 6x4x3/8

PL 11x5/8

COMBINED DYNAMIC STRESS
SECTION DT-2
(Due To Live Load And Acceleration Forces)
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn. June, July, 1953

FIG. 55



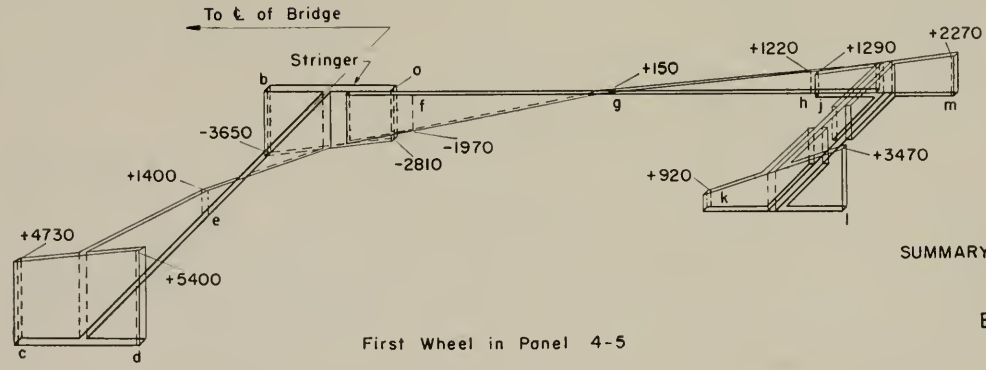
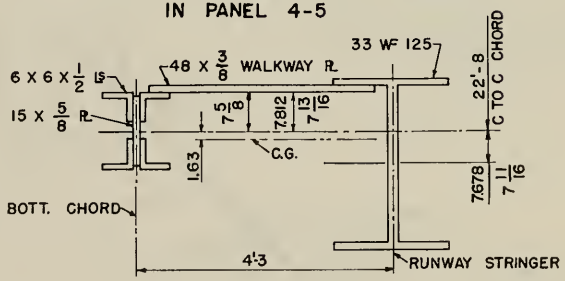


FIG. 56

SUMMARY OF MEASURED STATIC STRESSES
SECTION LM-1
ORE BRIDGE NO. 2
Edgar Thomson Steel Works
U.S. Steel Corp.
Braddock, Penn.
June, July, 1953

PROPERTIES OF BOTTOM CHORD COMBINATION IN PANEL 4-5

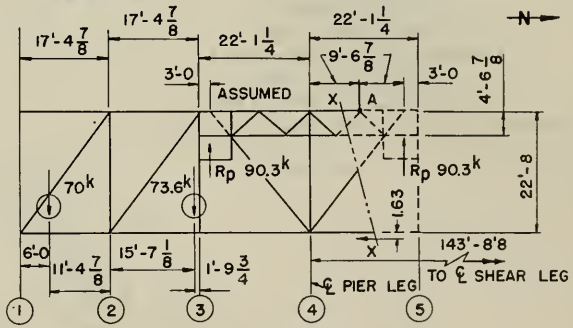


Stresses in members from field data
(Wheel loads and positions as shown)
Lower chord of $U_4 - U_5$ (gage UT2) = 16.82^k T
DIAGONAL $L_4 - U_5$ (gage DT2) = 58.1^k T
Vert. comp. of $L_4 - U_5 = 58.1 \times \frac{22.67}{29.64} = 44.4^k$

Bottom chord combination

Member	Area		Weighted ave. stress		Total stress
Bottom chord	$32.4^{\square''}$	x	$2.81^k/_{\square''}$	=	91.0^k
Walkway PL	$18.0^{\square''}$	x	$2.02^k/_{\square''}$	=	36.4^k
Runway stringer	$36.8^{\square''}$	x	$1.92^k/_{\square''}$	=	70.7^k
					198.1^k

EQUILIBRIUM CHECK OF FIELD READINGS



The trolley wheel loads shown are the weighted reactions as determined by the American Bridge Co.

Assume reactions at pier leg, Rp, to be equal.

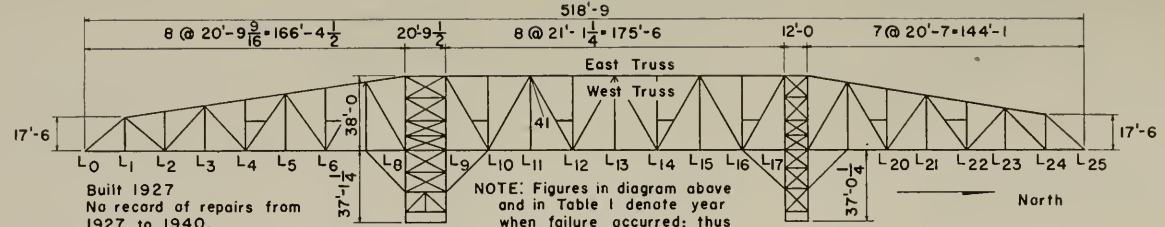
Determination of Rp (East truss)
(Sum moments about shear leg)
$2Rp \times 143.7 = 73.6 \times 167.6 + 70 \times 194.6 = 12\,335 + 13\,662 = 25\,957$
$Rp = \frac{25\,957}{287.4} = 90.3^k$

Sum of moments about point A
(Truss left of section X–X)

$70^k \times 60.5 =$	4230 ↷	(South wheel)
$73.6^k \times 33.5 =$	2470 ↷	(North wheel)
$44.4^k \times 9.6 =$	430 ↷	(Vert. comp. L_4-U_5)
$16.82^k \times 4.5 =$	80 ↷	(Lower chord U_4-U_5)
	7210 ↷	
$90.3 \times 28.7 =$	2590 ↶	(Tower react. Rp)
$91.0 \times 22.7 =$	2070 ↶	(Lower chord)
$36.4 \times 22.0 =$	800 ↶	(Walkway PL)
70.7×23.3	1650 ↶	(Stringer)
	7110 ↶	
	100^k ↶	

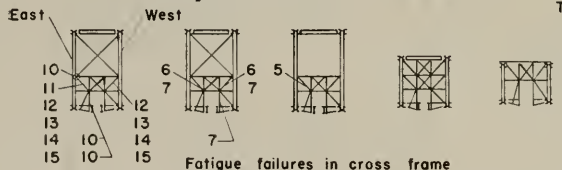
It can be seen that for all practical purposes the section is in equilibrium.

FIG. 57 CHECK OF PARTICIPATION STRESS IN FLOOR PLATE AND STRINGER.



Built 1927
No record of repairs from 1927 to 1940.
Repairs to main members and bracing made in 1941. Not described.

NOTE: Figures in diagram above and in Table I denote year when failure occurred; thus 46 denotes 1946.



Fatigue failures in cross frame located by panel points.

Panel Pts. 10-16 incl. | Panel Pts. 6,7 & 19. | Panel Pts. 4,5,20 & 21

Panel Pts. 8&9

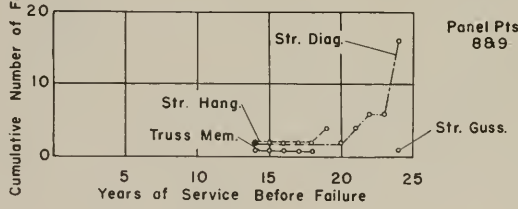


Table 1. Year of Failure in Cross Frame

Panel Point	Str. Hang. E.	Str. Hang. W.	Str. Diag. E.	Str. Diag. W.	Str. Guss. E.	Str. Guss. W.
0						
1						
2						
3						
4						
5			51			
6			51	51		
7		41	41	49		
8						
9	46		51			
10	41,46		41		51	
11			51			
12			51	48		
13			49	48		
14			51	51		
15			51	51		
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Total	4		16		1	

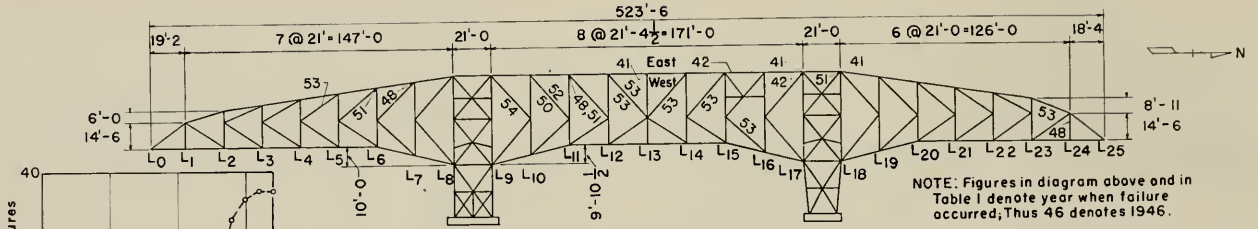
Table 2. Years of Service Before Failure

Year	Age	Str. Hang No.	Str. Hang Total	Str. Diag. No.	Str. Diag. Total	Str. Guss No.	Str. Guss Total	Total Cross Frame	Truss. No.	Truss. Total
41	14	2	2	2	2			4	1	1
42	15		2		2			4		1
43	16		2		2			4		1
44	17		2		2			4		1
45	18		2		2			4		
46	19	2	4		2			6		1
47	20		4		2			6		1
48	21		4	2	4			8		1
49	22		4	2	6			10		1
50	23		4		6			10		1
51	24		4	10	16	1	1	21		1
52	25									

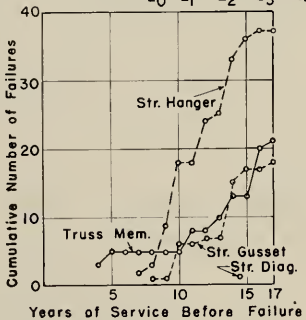
RECORD OF FATIGUE FAILURES

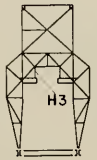
SOUTH WORKS U.S. STEEL CORPORATION
CHICAGO, ILLINOIS
ORE BRIDGE NO. 1 NORTH DOCK
L.T. Wyly; M.B. Scott Sept. 13, 1954
NOTE: Data supplied by American Bridge Division

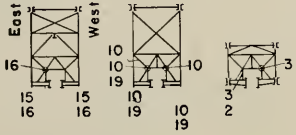
FIG. 58



NOTE: Figures in diagram above and in Table I denote year when failure occurred; Thus 46 denotes 1946.







Panel Pts. 15-16 | Panel Pts. 7,10&19 | Panel Pts. 2,3&23

Fatigue failures in cross frames located by panel points.

Panel Pts. 4-6, 11-19, 20-22 Incl.

Table 1. Year of Failure in Cross Frame

Panel Point	Str. Hanger E	Str. Hanger W	Str. Diag. E	Str. Diag. W	Str. Guss. E	Str. Guss. W
0						
1						
2	52					
3	46					51
4	47	51			51	47
5	52	47				
6	46	51			47	47,54
7		47,51				
8						
9						
10	49	51	51		51	51
11	52					
12	46	47	52		51	51
13		44				45,47
14	53	46				51
15	46	49				
16	47	51			49,51	
17						
18						
19	45	51			52	
20	51					51
21	51					
22	46	49				52
23						
24						
TOWER	44					
TOTAL	29		21		18	

Table 2. Years of Service Before Failure

Year	Age	Str. Hanger No.	Str. Hanger Total	Str. Diag. No.	Str. Diag. Total	Str. Guss. No.	Str. Guss. Total	Total Cross Frame	Truss No.	Truss Total
41	4								3	3
42	5								2	5
43	6									5
44	7	2	2					2		5
45	8	1	3			1	1	4		5
46	9	6	9				1	10		5
47	10	9	18			5	6	24		5
48	11		18				6	24	3	8
49	12	6	24			1	7	31		8
50	13	1+	25+				7	32+	2	10
51	14	8	33+	1	1	8	15	49+	3	13
52	15	3	36+	1	2	2	17	55+	1	13
53	16	1	37+		2		17	56+	7	20
54	17		37+		2	1	18	57+	1	21

NOTE: Built 1937
No recorded repairs from 1937 to 1940
Top chords reinforced for heavier trolley than original design in 1941-2.
Chords are silicon steel between Panel Points 4 and 21

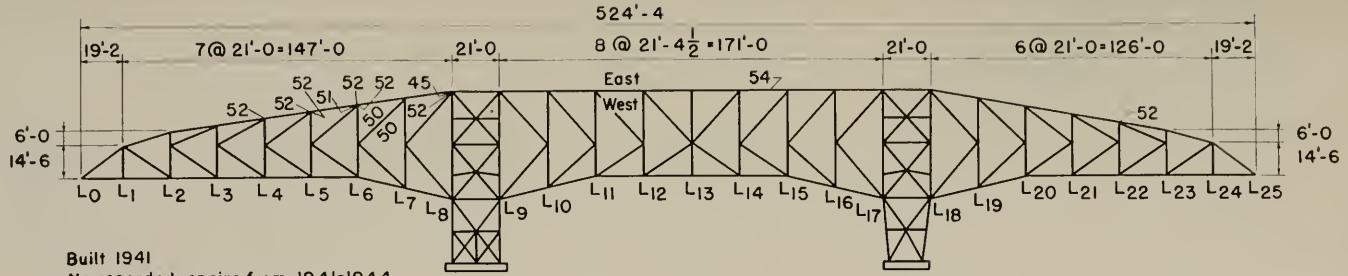
Not in Table I

1947	4 other Stringer Hangers.	Not located	
1949	1 Hanger Gusset, west.	Not located	
	2 Hanger	Not located	
1950	Hangers, Gussets found.	Not located	Number not given
	Top Chord	Not located	

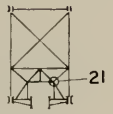
RECORD OF FATIGUE FAILURES

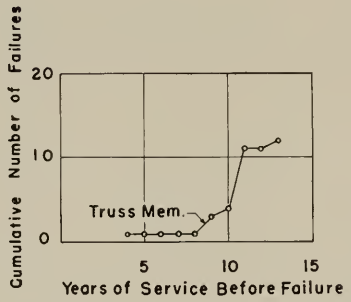
SOUTH WORKS U.S. STEEL CORPORATION
CHICAGO, ILLINOIS
ORE BRIDGE NO. 2 NORTH DOCK
L.T. Wyly; M.B. Scott Sept. 13, 1954
NOTE: Data supplied by American Bridge Division

FIG. 59



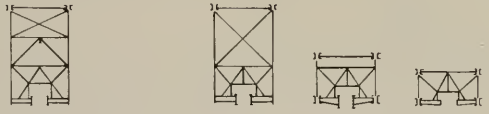
Built 1941
No recorded repairs from 1941-1944
Chords are silicon steel between
Panel Points 4 and 21





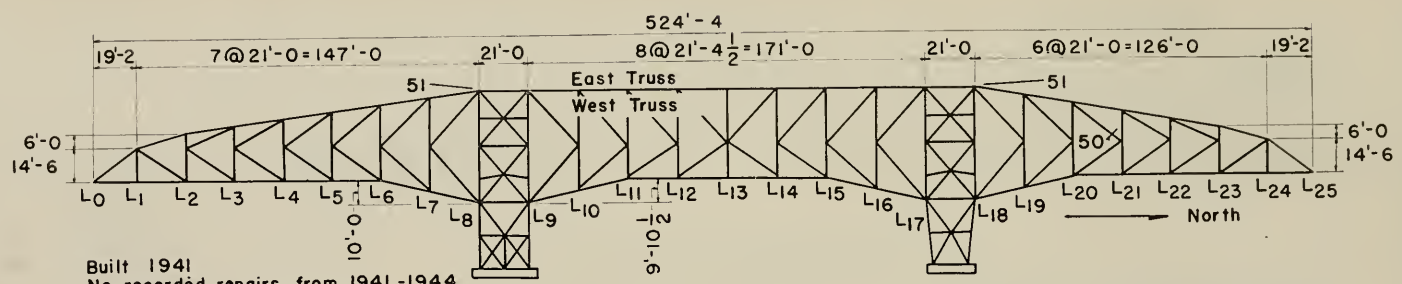
Years of Service Before Failure

Year	Age	Truss	
		No.	Total
45	4	1	1
46	5		1
47	6		1
48	7		1
49	8		1
50	9	2	3
51	10	1	4
52	11	7	11
53	12		11
54	13	1	12



RECORD OF FATIGUE FAILURES
SOUTH WORKS U.S. STEEL CORPORATION
CHICAGO, ILLINOIS
ORE BRIDGE NO.3 NORTH DOCK
L.T. Wyly; M.B. Scott Sept.13, 1954
NOTE: Data supplied by American Bridge Division

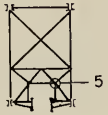
FIG. 60

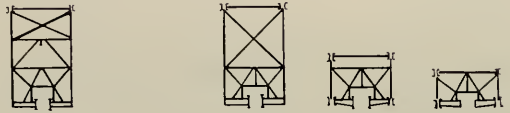


Built 1941
No recorded repairs from 1941-1944
Chords are silicon steel between
Panel Points 4 and 21

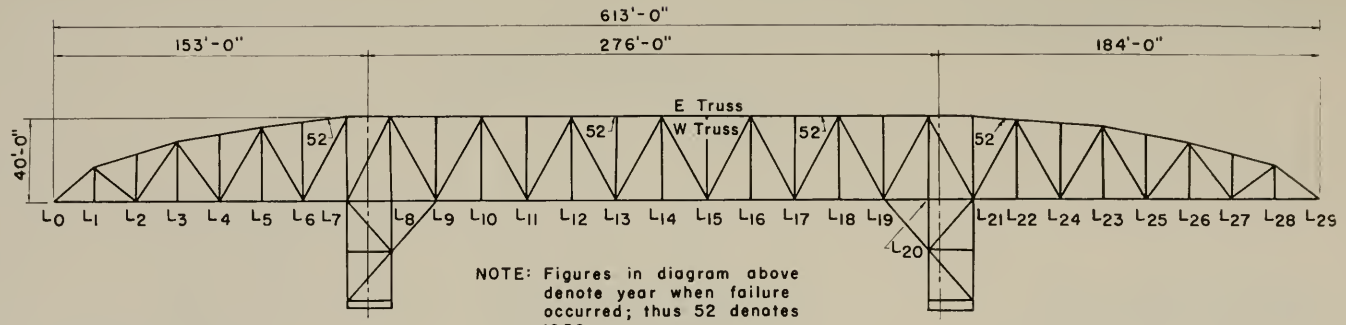
Years of Service Before Failure

Year	Age	Truss	
		No.	Total
50	9	1	1
51	10	2	3
53	11		





RECORD OF FATIGUE FAILURES
SOUTH WORK U.S. STEEL CORPORATION
CHICAGO, ILLINOIS
ORE BRIDGE NO. 4 NORTH DOCK
L.T. Wyly; M.B. Scott June 9, 1954
NOTE: Data supplied by American Bridge Division
FIG. 61

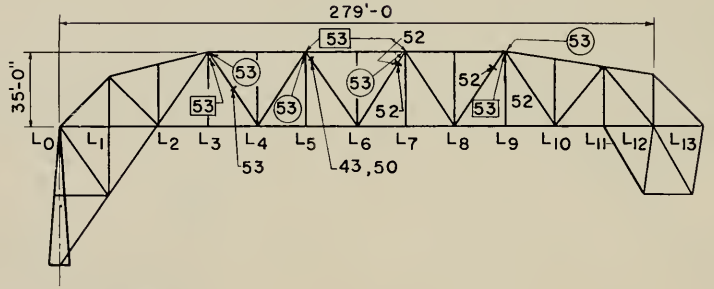


NOTE: Figures in diagram above denote year when failure occurred; thus 52 denotes 1952.

NOTE: Built in 1906
No detailed record of repairs previous to 1949.
In 1913, 200 tons of reinforcing material were added.
In 1924 and 1943 the structure was damaged by violent wind storms, and repairs were made.

FIG. 62
RECORD OF FATIGUE FAILURES
U.S. STEEL CORPORATION
PITTSBURGH, PENNSYLVANIA
ORE BRIDGE A

L.T. Wyly; M.B. Scott April 23, 1954
NOTE: Data supplied by American Bridge Division



NOTE: Figures in diagram above denote year when failure occurred; thus 43 denotes 1943.
Figures shown (43) denotes gusset failure on South Truss.
Figures shown [43] denotes gusset failure on North Truss.
Other figures indicate a failure in the member.

NOTE: Built in 1907
No record of repairs between 1907 & 1941
1941: Cracked hanger Rs replaced whose number and location are not given.
1952: Apparently all stringer hangers & gussets replaced–damage not given.

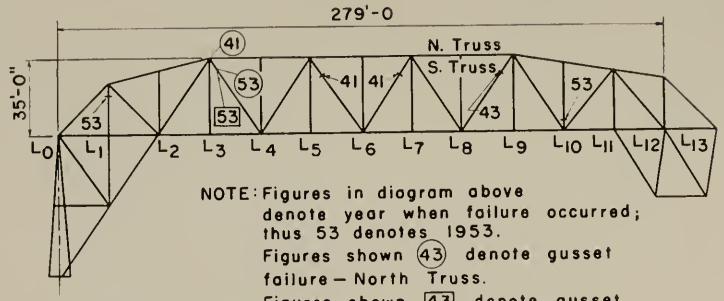
'Foilures occurred in 1952 & 1953
Cracked stringer gussets found in 1941 and replaced.

Year	Age	Truss Gussets	Truss Diagonal
43	36		1
50	43		1
52	45		4
53	46	11	1
Total		11	7

NOTE: The years of service may be much less than shown by above table since repair history before 1941 is lacking.

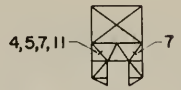
FIG. 63
RECORD OF FATIGUE FAILURES
U.S. STEEL CORPORATION
PITTSBURGH, PENNSYLVANIA
ORE BRIDGE "B"

L.T. Wyly; M.B. Scott April 23, 1954
NOTE: Data supplied by American Bridge Division



NOTE: Figures in diagram above denote year when failure occurred; thus 53 denotes 1953.
Figures shown (43) denote gusset failure — North Truss.
Figures shown [43] denote gusset failure — South Truss.
Other figures indicate a failure in the member.

NOTE: Built in 1907
No record of failures between 1907 and 1941.
1941: Replaced several hanger gusset ℄s — damage not given.
1947: Repaired stringer hanger ℄s in panel 4.
1952: Replaced all honger gusset ℄s.



Failures occurred in 1951 and 1952

Years of Service Before Failure

Year	Age	Truss Gussets	Truss Webs
41	34	1	2
43	36	2	1
53	46		2
Total		3	5

NOTE: The years of service may be much less than shown by above table since repair history before 1941 is lacking.

FIG. 64
RECORD OF FATIGUE FAILURES
U.S. STEEL CORPORATION
PITTSBURGH, PENNSYLVANIA
ORE BRIDGE C

L.T. Wyly; M.B. Scott April 23, 1954
NOTE: Data supplied by American Bridge Division

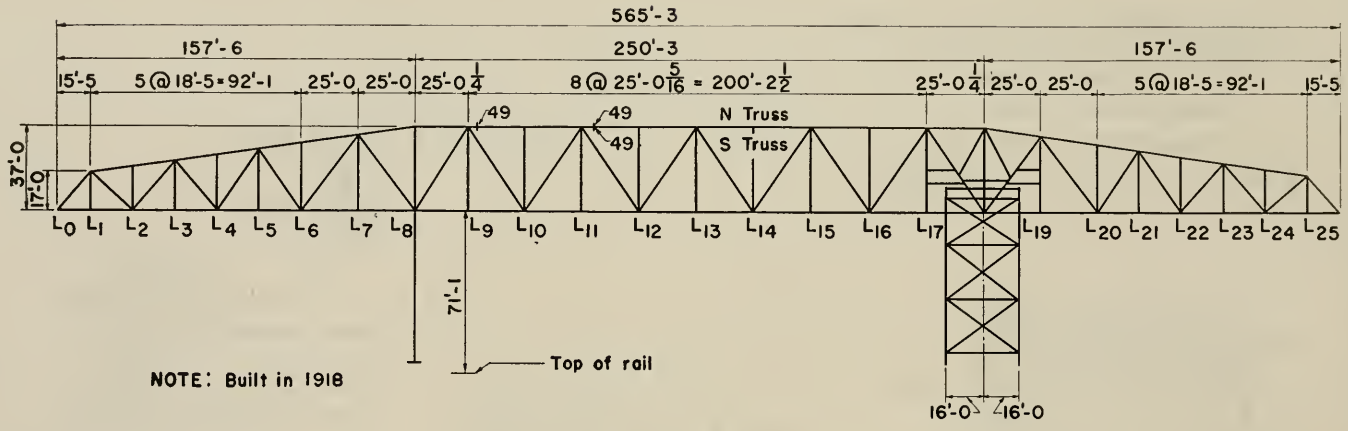


FIG. 65

RECORD OF FATIGUE FAILURES

U.S. STEEL CORPORATION

PITTSBURGH, PENNSYLVANIA

ORE BRIDGE "D"

L.T. Wyly ; M.B. Scott April 23, 1954

NOTE: Data supplied by American Bridge Division

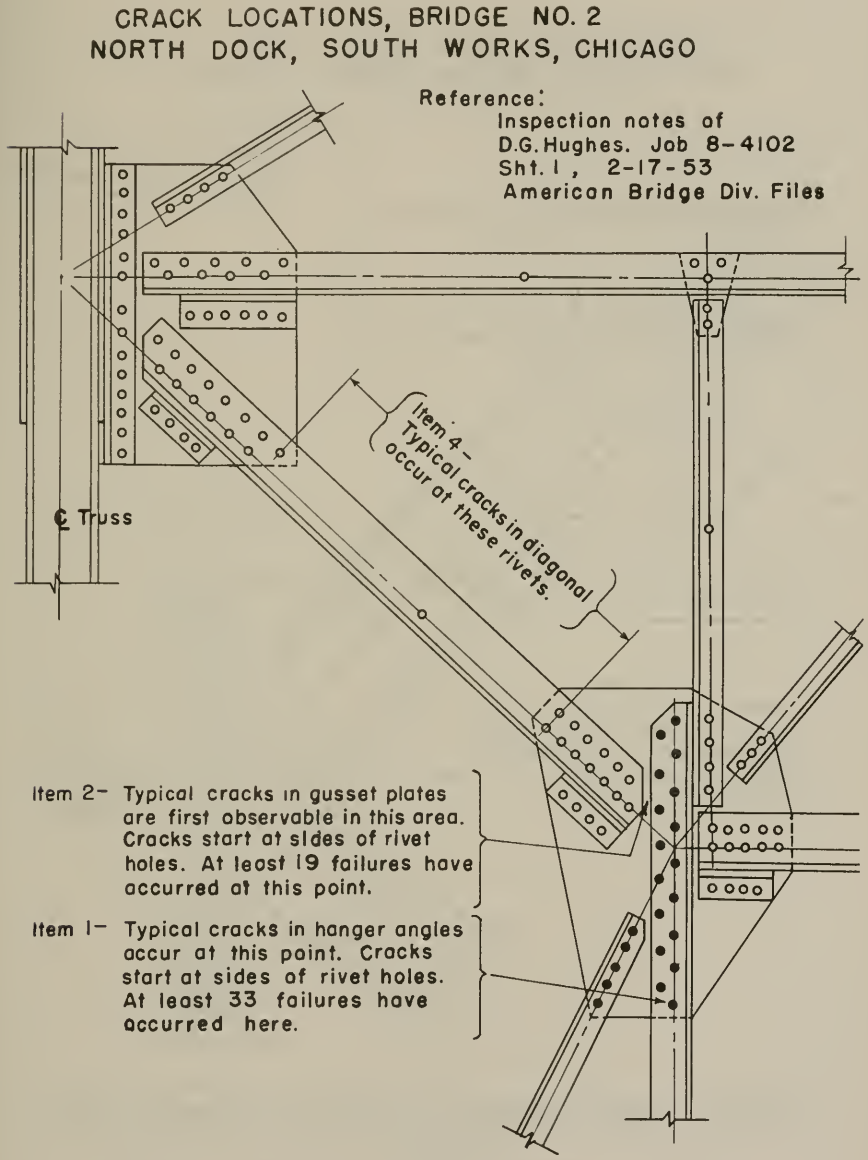
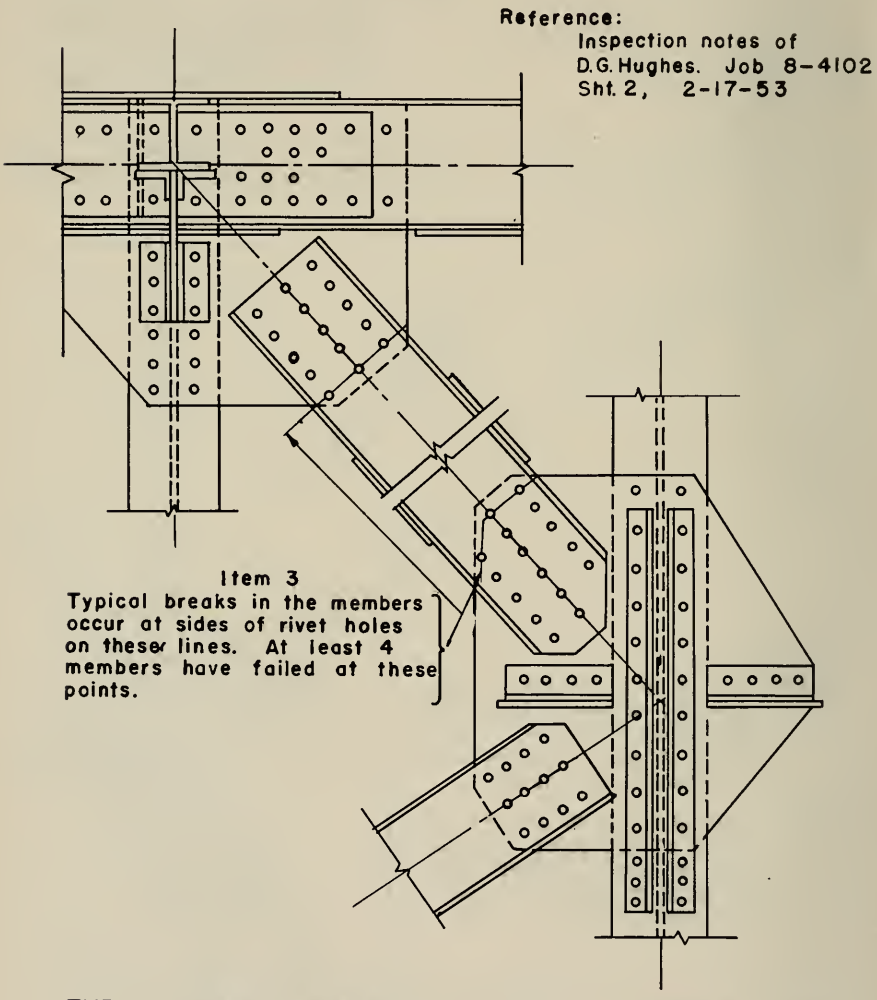

CRACK LOCATIONS, BRIDGE NO. 2
NORTH DOCK, SOUTH WORKS, CHICAGO
Reference:
Inspection notes of
D.G. Hughes. Job 8-4102
Sht. 1, 2-17-53
American Bridge Div. Files
℄ Truss
Item 4 - Typical cracks in diagonal occur at these rivets.
Item 2- Typical cracks in gusset plates are first observable in this area. Cracks start at sides of rivet holes. At least 19 failures have occurred at this point.
Item 1- Typical cracks in hanger angles occur at this point. Cracks start at sides of rivet holes. At least 33 failures have occurred here.

FIG. 66 TYPICAL CROSSFRAME FAILURES

CRACK LOCATIONS, BRIDGE NO. 2
NORTH DOCK, SOUTH WORKS, CHICAGO


Reference:
Inspection notes of
D.G. Hughes. Job 8-4102
Sht. 2, 2-17-53
Item 3
Typical breaks in the members occur at sides of rivet holes on these lines. At least 4 members have failed at these points.

TYPICAL UPPER DIAGONAL FAILURE IN CENTER SPAN
FIG. 67

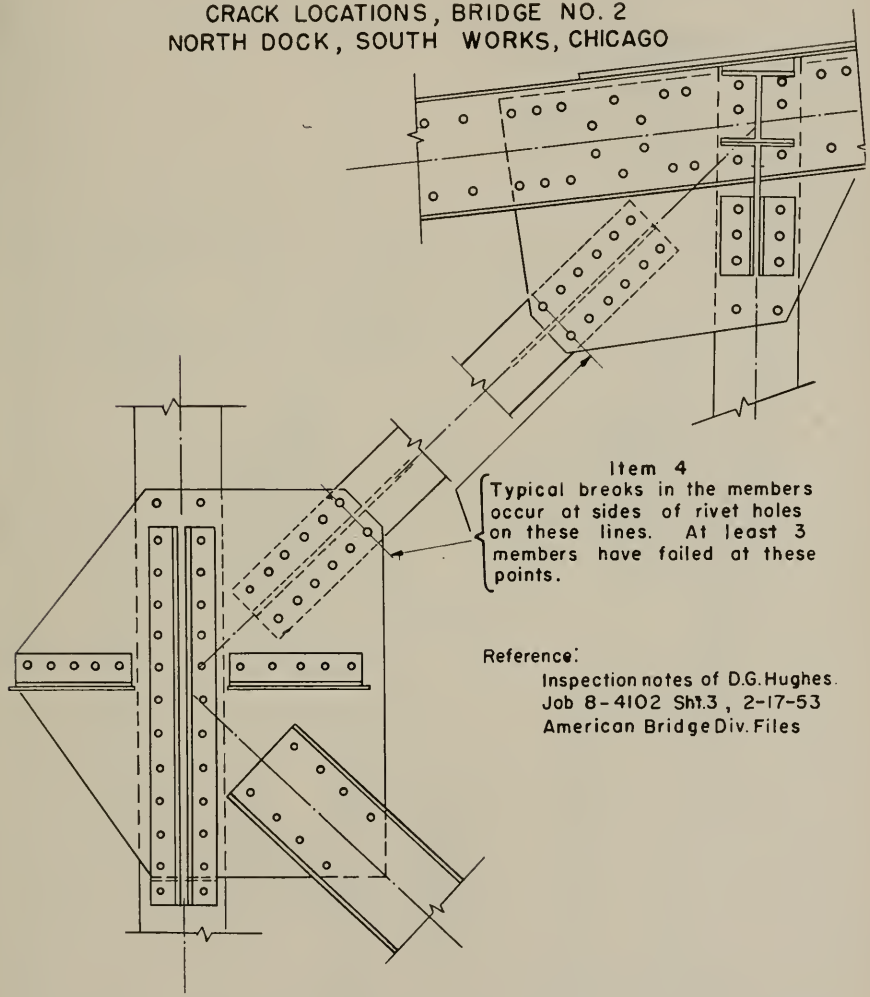

CRACK LOCATIONS, BRIDGE NO. 2
NORTH DOCK, SOUTH WORKS, CHICAGO
Item 4
Typical breoks in the members occur at sides of rivet holes on these lines. At least 3 members have failed at these points.
Reference:
Inspection notes of D.G. Hughes.
Job 8-4102 Sht.3, 2-17-53
American Bridge Div. Files

FIG. 68 TYPICAL UPPER DIAGONAL FAILURE IN CANTILEVER

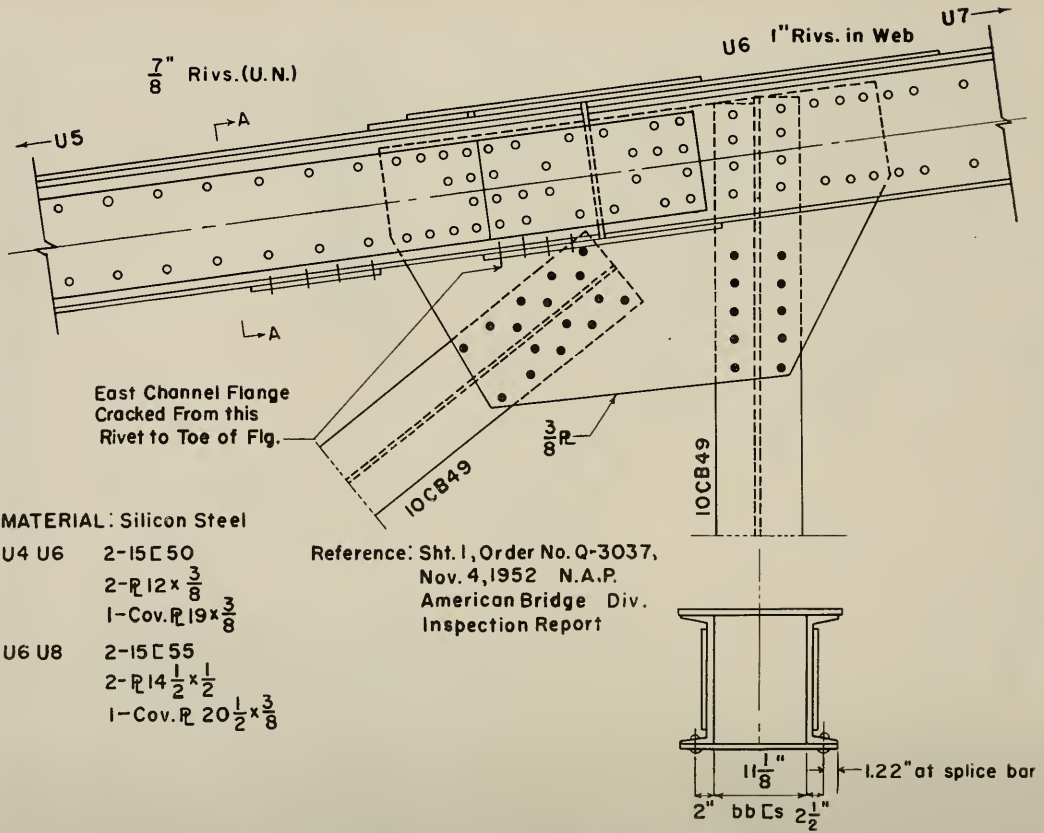


FIG. 69 CRACK AT U_6 WEST – BRIDGE NO. 3 NORTH DOCK SOUTH WORKS

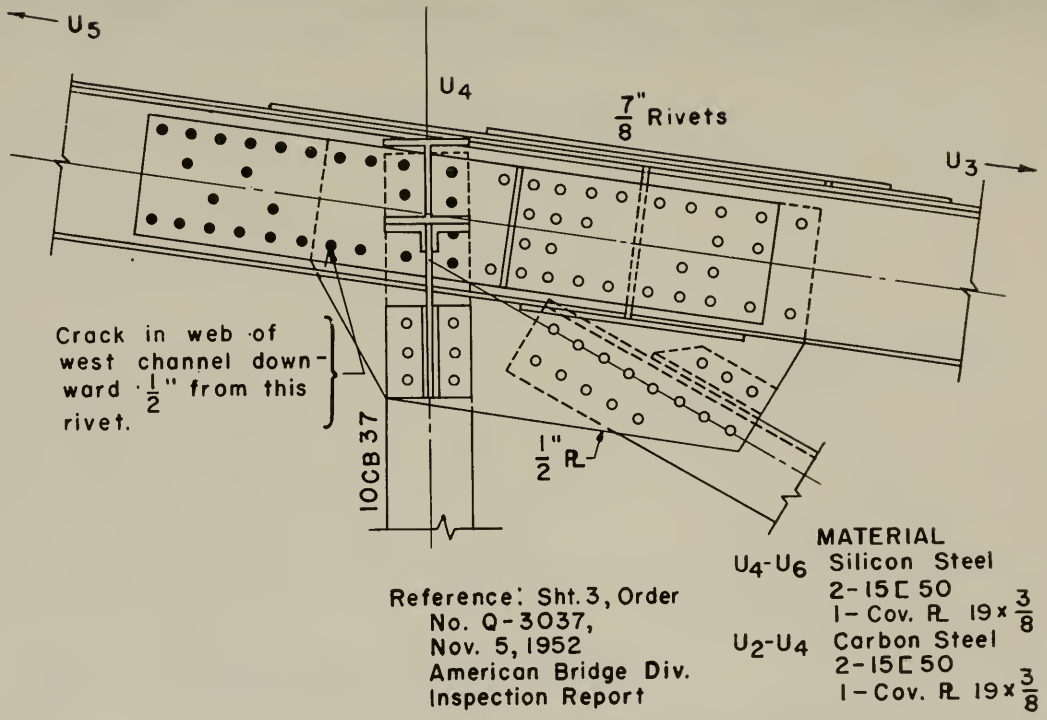
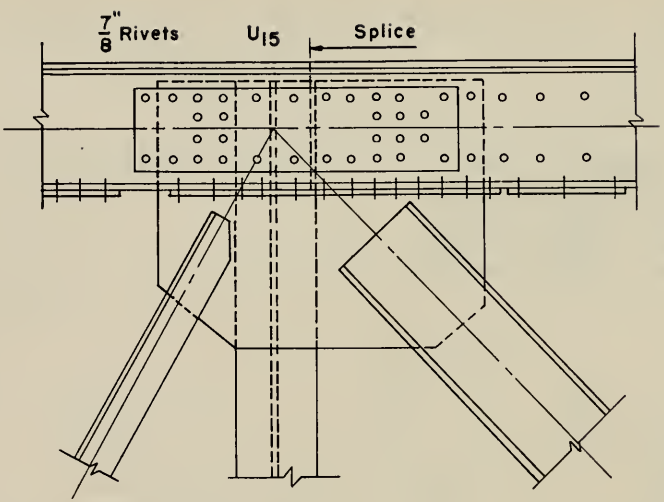


FIG. 70 CRACK AT U_4 EAST - BRIDGE NO. 3 NORTH DOCK SOUTH WORKS



MATERIAL: Silicon Steel
U_{13}-U_{15} 2 - 15C33.9
2 - PL $14\frac{1}{2} \times \frac{1}{2}$
U_{15}-U_{17} 2 - 15E40
2 - PL $14\frac{1}{2} \times \frac{1}{2}$

Reference: Sht. 1
Feb. 2, 1954 A.P.A
American Bridge Div.
Inspection Report

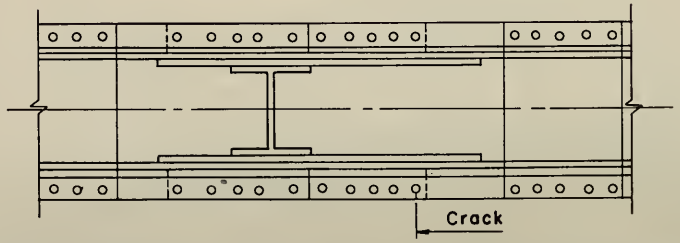


FIG. 71 CRACK AT U_{15} EAST - BRIDGE NO. 3 NORTH DOCK SOUTH WORKS

REFERENCE: History of Repairs to Ore Bridge No. 1, Dean G. Hughes, P. 2
North Dock South Works G-9267-1941-42 Repairs (Roetter)

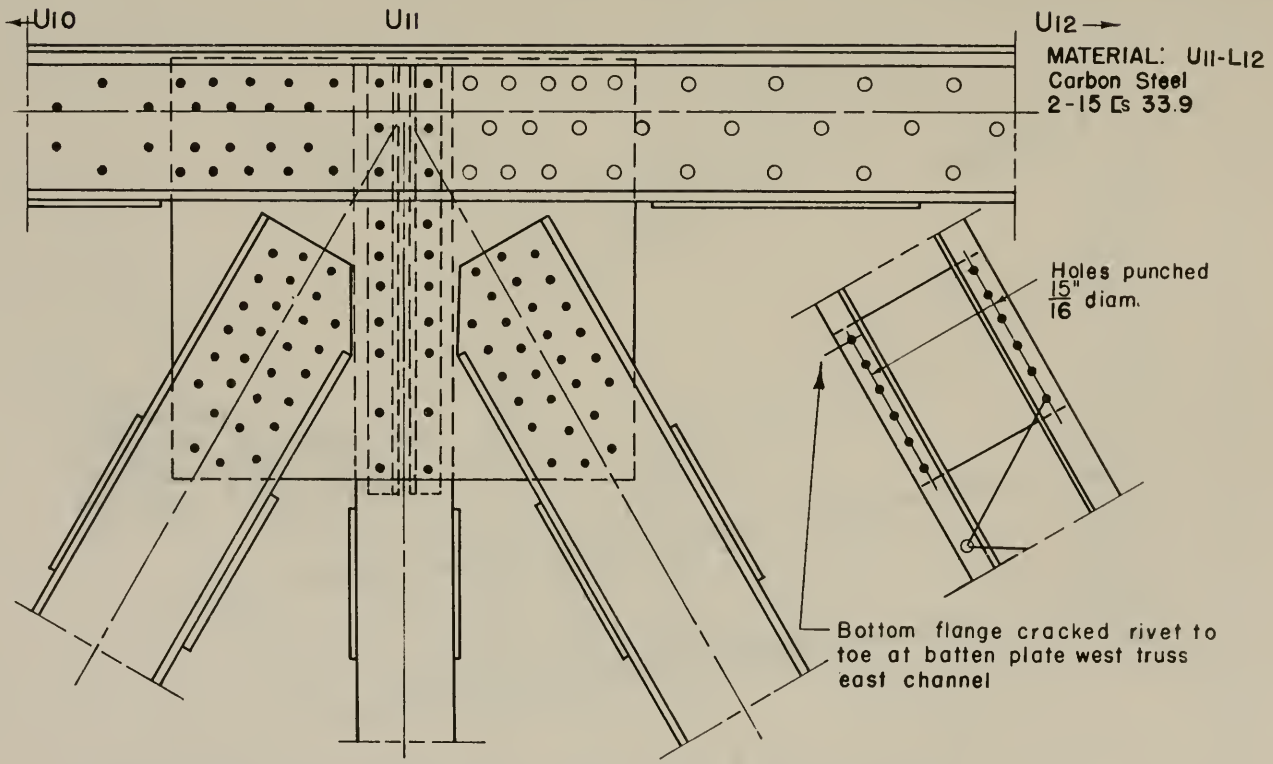


FIG. 72 CRACK AT U_{11} BRIDGE NO. 1 NORTH DOCK SOUTH WORKS

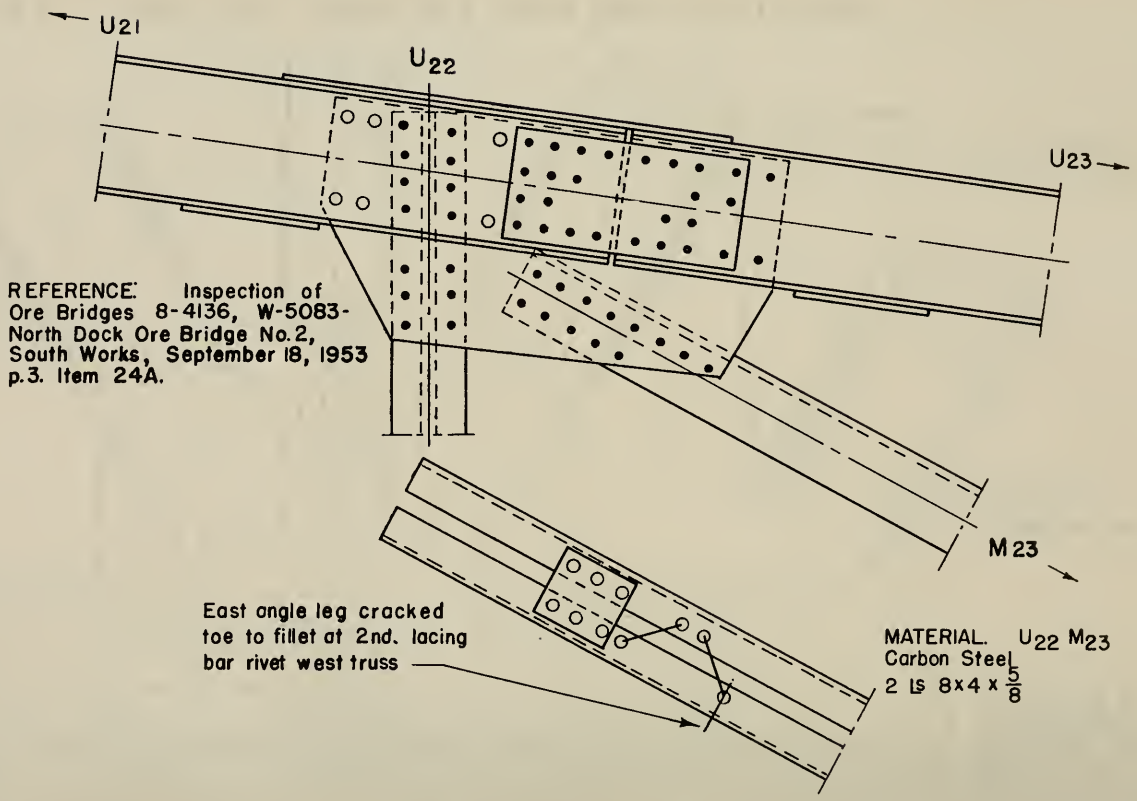

U21
U22
U23
M23
REFERENCE: Inspection of Ore Bridges 8-4136, W-5083- North Dock Ore Bridge No. 2, South Works, September 18, 1953 p.3. Item 24A.
East angle leg cracked toe to fillet at 2nd. lacing bar rivet west truss
MATERIAL. U22 M23
Carbon Steel
2 ls 8x4 x 5/8

FIG. 73 CRACK AT U_{22} BRIDGE NO. 2 NORTH DOCK SOUTH WORKS

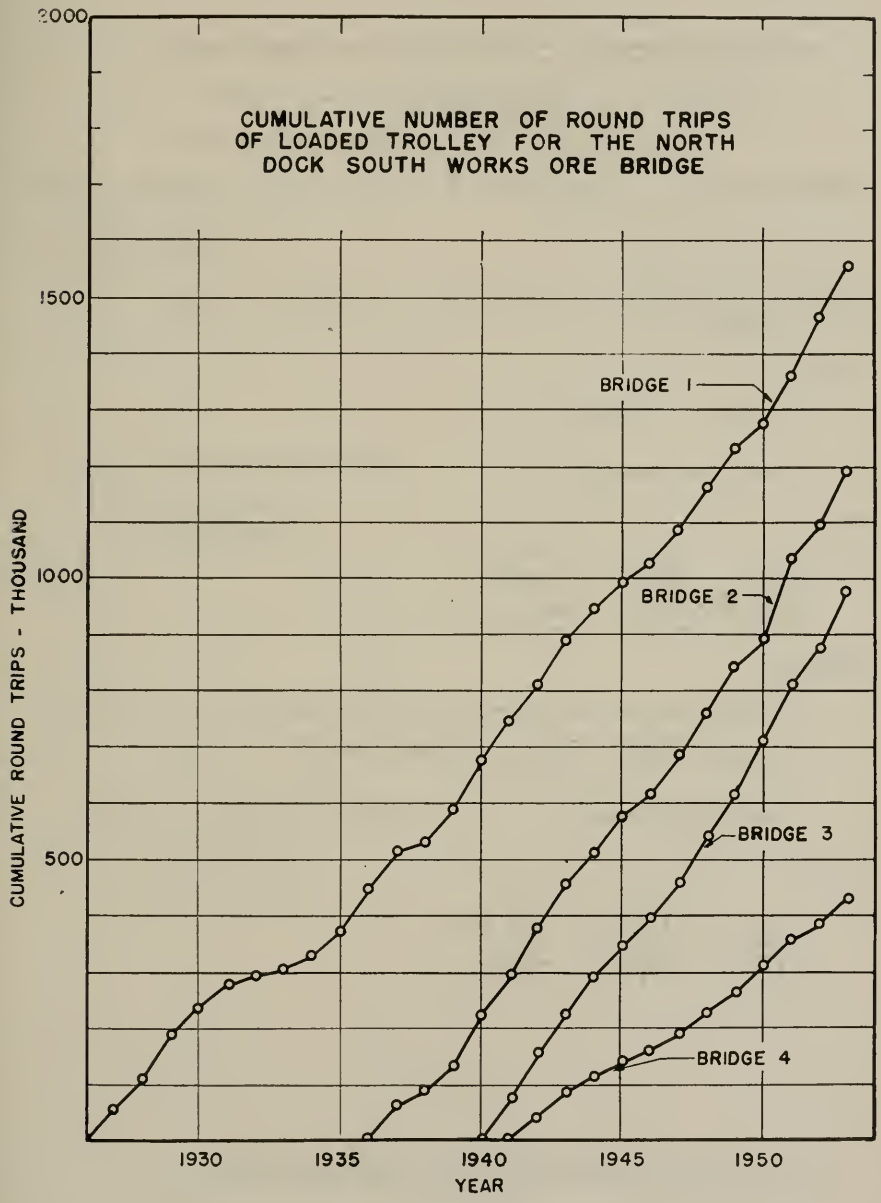

CUMULATIVE NUMBER OF ROUND TRIPS
OF LOADED TROLLEY FOR THE NORTH
DOCK SOUTH WORKS ORE BRIDGE
2000
1500
1000
500
CUMULATIVE ROUND TRIPS - THOUSAND
BRIDGE 1
BRIDGE 2
BRIDGE 3
BRIDGE 4
1930
1935
1940
1945
1950
YEAR

FIG. 74

CROSS FRAMES, BRIDGE NO. 1, NORTH DOCK, SOUTH WORKS, CHICAGO

References: 1. Design Drawings 45501-A, B 1927
2. Shop Details
3. Figs. 9, 13, of Part 1 of this report

Trolley Loading: 5 Wheels at 24 k Reference: 1. Stress Sheet 45501-A 1927
2. Letter from Mr. Greene, Dated 6-7-54

Stringer Reaction at Truss Panel Point $R = 3.32 \times 24 = 79.5$ k
No Continuity

Hanger

Load $H = 79.5 \times \frac{4.87}{4.14} = 93.5$ k

Axial Unit Stress $\frac{P}{A}$ Section 2 Angles 6 x 4 x 5/8

$A_g = 11.72$ in.^{2}
$A_n = 10.47$ in.^{2}

	Ag	An
LL	8.0 ksi	9.0 ksi
30% Imp.	2.4	2.7
LL + I	10.4 ksi	11.7 ksi

Diagonal

Assume stringer brace carries vertical component of 0.5 (H - R)

Load $D = \frac{10.29}{7} \times \left[93.5 - 0.5\,(93.5 - 79.5)\right] = 126$ k

Axial Unit Stress $\frac{P}{A}$ Section 2 Angles 6 x 4 x 1/2

$A_g = 9.50$ in.^{2}
$A_n = 8.50$ in.^{2}

	Ag	An
LL	13.2 ksi	14.8 ksi
30% Imp.	4.0	4.3
LL + I	17.2 ksi	19.1 ksi

FIG. 75 ESTIMATED STRESS HISTORY OF HANGERS AND DIAGONALS

CROSS FRAMES, BRIDGE NO. 2, NORTH DOCK, SOUTH WORKS, CHICAGO

References: 1. Design Drawings 7402: S1, S2A, S2B, S3, S7
2. Shop Details
3. Figs. 9, 13, of Part 1 of this report

Trolley Loading: 6 Wheels at 25 k or
5 Wheels at 30 k

Reference:
1. Stress Sheet 7402-S3, Dated 12-2-40
2. Letter from Mr. Greene Dated 6-7-54

Stringer Reaction at Truss Panel Point Continuity Acting

R = 4.07 x 25 = 102 k or
R = 3.35 x 30 = 101 k

Hanger

Load H = 1.16 x 102 = 118 k

Axial Unit Stress $\frac{P}{A}$

Section 2 Angles 6 x 4 x 5/8
2 h 1"

A_g = 11.72 in.^{2}
A_n = 10.47 in.^{2}

	Ag	An
LL	10.1 ksi	11.2 ksi
30% Imp.	3.0	3.1
LL + I	13.1 ksi	14.3 ksi

Diagonal

Assume stringer brace carries vertical component of .5 (H - R)

Load D = $\frac{10.23}{6.96}$ x $\left[118 - 0.5\ (118 - 102)\right]$ = 162 k

Axial Unit Stress $\frac{P}{A}$

Section 2 Angles 8 x 4 x 3/4
4 h 1"

A_g = 16.88 in.^{2}
A_n = 13.88 in.^{2}

	Ag	An
LL	9.6 ksi	11.6 ksi
30% Imp.	2.9	3.5
	12.5 ksi	15.1 ksi

FIG. 76 ESTIMATED STRESS HISTORY OF HANGERS AND DIAGONALS

CROSS FRAMES, BRIDGES NO. 3, 4, NORTH DOCK, SOUTH WORKS, CHICAGO

References: 1. Design Drawings 7402: S1, S2A, S2B, S3, S7
2. Shop Details
3. Figs. 9, 13, of Part 1 of this report

Trolley Loading: 5 Wheels at 38 k Reference: 1. Stress Sheet 7402-S3
2. Letter from Mr. Greene, Dated 6-7-54

Stringer Reaction at Truss Panel Point $R = 3.51 \times 38 = 134$ k
Continuity Acting

Hanger

Load $H = 1.16 \times 134 = 155$ k

Axial Unit Stress $\frac{P}{A}$ Section 2 Angles 6 x 4 x 3/4 2 h 1"

$A_g = 13.88$ in.^{2}
$A_n = 12.38$ in.^{2}

LL	Ag	An
LL	11.2 ksi	12.5 ksi
30% Imp.	3.4	3.8
LL + I	14.6 ksi	16.3 ksi

Diagonal

Assume stringer brace carries vertical component of 0.5 (H - R)

Load $D = \frac{10.23}{6.96} \times \left[155 - 0.5\,(155 - 134)\right] = 213$ k

Axial Unit Stress $\frac{P}{A}$ Section 2 Angles 8 x 4 x 13/16
4 h 1"

$A_g = 18.18$ in.^{2}
$A_n = 14.93$ in.^{2}

	Ag	An
LL	11.7 ksi	14.2 ksi
30% Imp.	3.5	4.2
LL + I	15.2 ksi	18.4 ksi

FIG. 77 ESTIMATED STRESS HISTORY OF HANGERS AND DIAGONALS

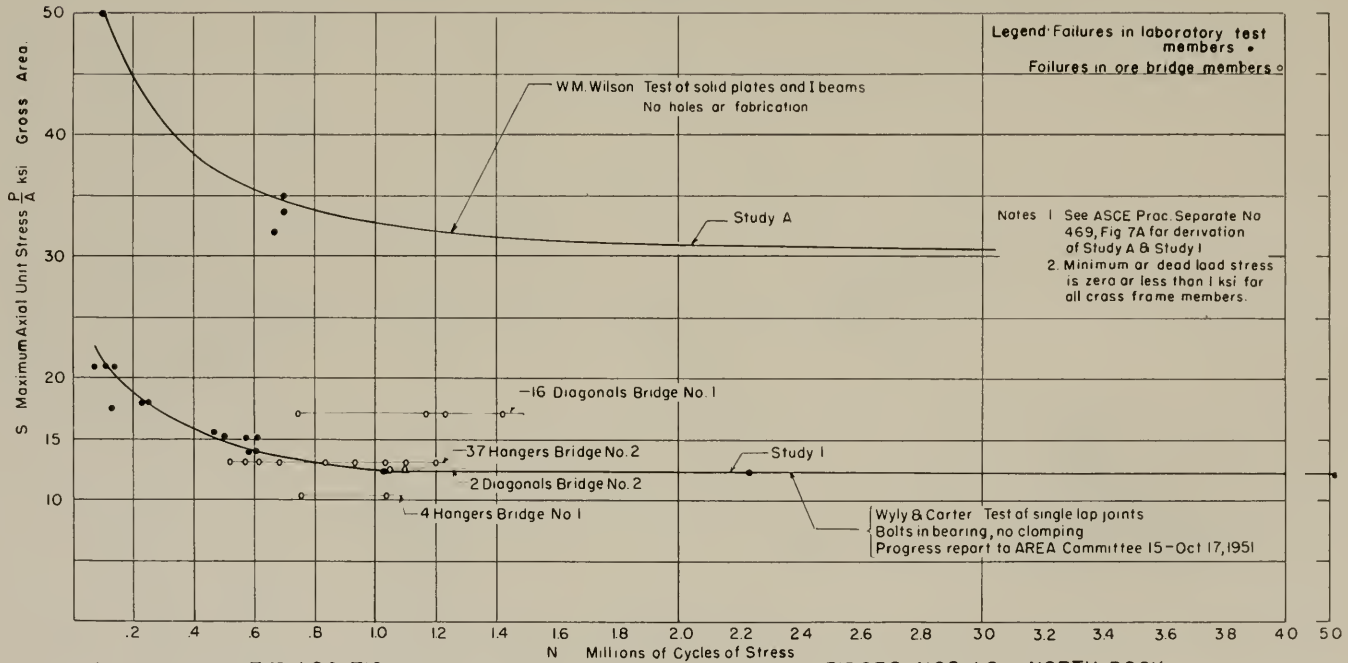

S Maximum Axial Unit Stress P/A ksi Gross Area
50
40
30
20
15
10
Legend: Failures in laboratory test members •
Failures in ore bridge members ○
W.M. Wilson Test of solid plates and I beams
No holes or fabrication
Study A
Notes 1 See ASCE Proc. Separate No 469, Fig 7A for derivation of Study A & Study I
2. Minimum or dead load stress is zero or less than 1 ksi for all cross frame members.
16 Diagonals Bridge No. 1
37 Hangers Bridge No. 2
Study I
2 Diagonals Bridge No. 2
4 Hangers Bridge No 1
Wyly & Carter Test of single lap joints
Bolts in bearing, no clamping
Progress report to AREA Committee 15 - Oct 17, 1951
.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 5.0
N Millions of Cycles of Stress

Fig. 78 ESTIMATED LOCATION ON S-N DIAGRAM OF FRAME FAILURES, BRIDGES NOS. 1,2. NORTH DOCK

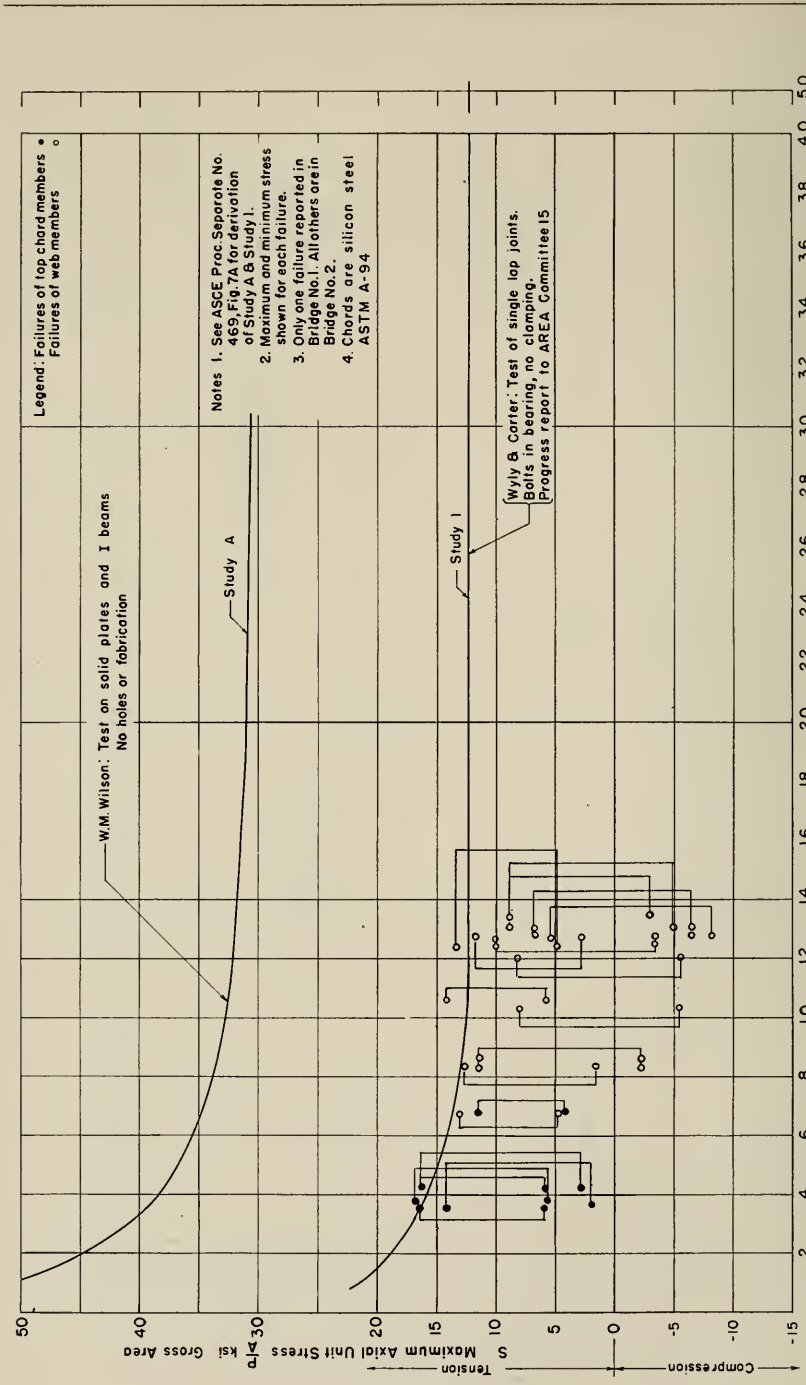

Legend: Failures of top chord members •
Failures of web members ○
W.M. Wilson: Test on solid plates and I beams
No holes or fabrication
Study A
Notes 1. See ASCE Proc. Separate No. 469, Fig. 7A for derivation of Study A & Study I.
2. Maximum and minimum stress shown for each failure.
3. Only one failure reported in Bridge No. 1. All others are in Bridge No. 2.
4. Chords are silicon steel ASTM A-94
Study I
Wyly & Carter: Test of single lap joints. Bolts in bearing, no clamping. Progress report to AREA Committee 15
S Maximum Axial Unit Stress ksi Gross Area
Tension
Compression
N. Millions of Cycles of Stress

FIG. 79 ESTIMATED LOCATION ON S-N DIAGRAM OF TRUSS FAILURES, BRIDGES NOS. 1,2. NORTH DOCK SOUTH WORKS

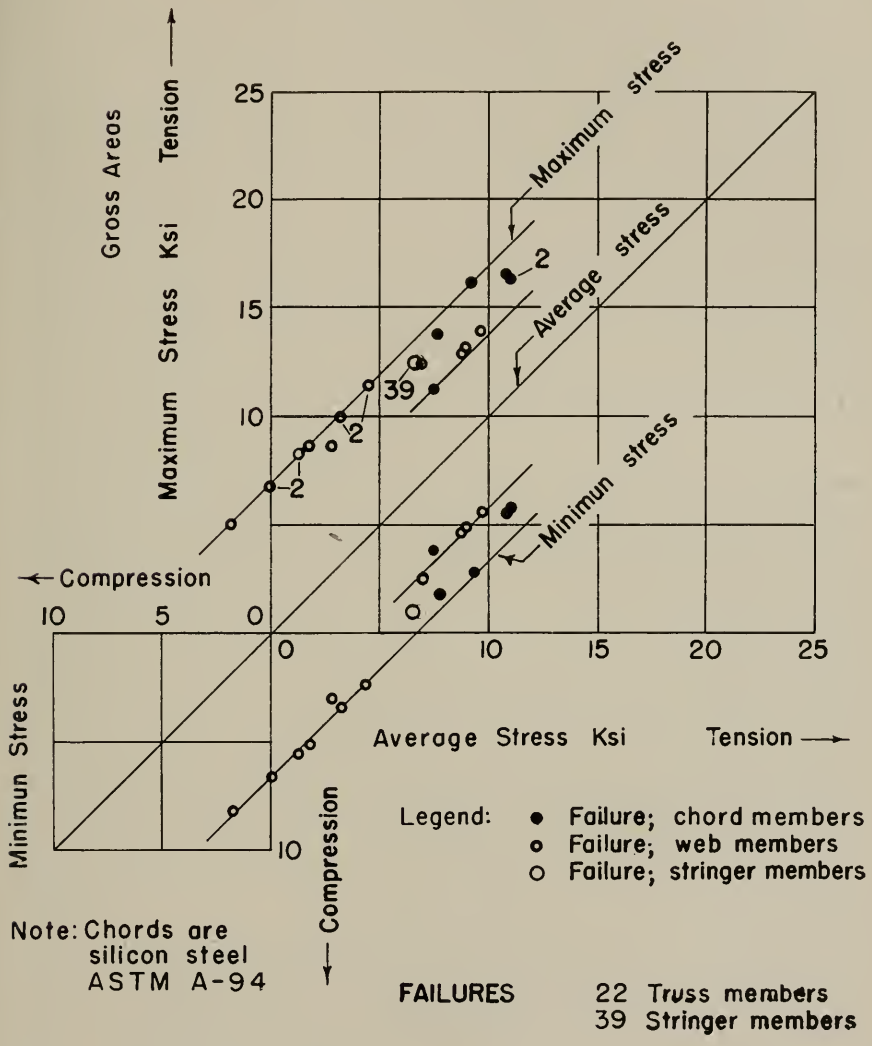


FIG. 80 EFFECT OF RANGE OF STRESS ON ENDURANCE LIMIT ORE BRIDGE NO. 2 NORTH DOCK SOUTH WORKS FAILURES OF RIVETED TRUSS MEMBERS

Report on Joint Metallurgical Societies Meeting in Europe—1955

By R. E. Cramer

Research Associate Professor of Engineering Materials, University of Illinois

This is a highlight report on the joint meetings of the American Society for Metals and the American Institute of Mining and Metallurgical Engineers with the metallurgical societies of Great Britain, Germany, Belgium, Sweden and France, held in Europe, June 1 to 19, 1955. Reference is made only to those papers which dealt with railroad rails.

Meetings in London

Two technical sessions were held in London in which the writer was particularly interested. The first was on the continuous casting of blooms. The reports covered the continuous casting of blooms of aluminum, copper, and steel. The writer found that no work was reported on high-carbon steels of the grade used for rails and the larger blooms used were mostly of the slab type 2 to 3 in thick and 8 to 12 in wide. No report was made of casting blooms 9 by 9 in square, or the size which would be required to roll into railroad rails. Actually, most of the continuous casting of steel blooms is still in the experimental stages, but there are some indications that the process has merit and can be developed further for larger blooms.

The second session of interest in London was on the production of steel ingots of high quality by processes other than continuous casting. This session dealt with segregation in ingots and the effect of various treatments of the metal to prevent segregation. Dr. Fairley spoke on hydrogen in steel and its effect of lowering the ductility of steel.

My most interesting contacts in London were with Alex Sandberg, whose father developed the Sandberg slow-cooling process for railroad rails. At present the Sandberg Company is not inspecting rails for the government-owned railroads, but Mr. Sandberg introduced me to L. G. B. Rock, assistant engineer, permanent way, Southern Railways, Waterloo Station, London. I spent a full day with Mr. Rock discussing their rail failures and seeing reports on these failures. For the last several years he has been compiling statistics on their rail failures, which I believe are much fewer than on most American railroads due to their comparatively light wheel loads. Their grouping of failures is somewhat different than in AREA statistics as for example, their group 3, called longitudinal splits, includes horizontal and vertical split heads as well as horizontal web cracks. He gave me the following percentage figures:

Type Number	*Description of Failure*	*Percent of Total*
1	Sudden transverse fracture	4
2	Transverse fatigue or two-stage fracture (includes TF and DF from shelling)	34
3	Longitudinal splits (VSH, horizontal split heads and horizontal web failures)	12
4	Rail end failures (within 2 ft of rail end)	
	a. Transverse crack or break	4
	b. Longitudinal web crack, generally over the first chair beyond angle bars	3
	c. A piece broken out of the head (head and web crack starting at rail end)	10
	d. Diagonal fracture through first bolt hole	20
5	Corrugated rail	6

(Table continued on next page)

Type Number	*Description of Failure*	*Percent of Total*
6	Wheel slips, slide or burn	4
7	Corner flaking	..
8	Crushed head	..
9	Cracked web (generally starting from a hole through web away from rail end)	3
	Total	100

I found from examining pictures of their failures that they have quite a few failures which the AREA now classifies as detail fracture from shelling, but they do not distinguish these from transverse fissures and all are included in their type 2 failures. They have very few transverse fissures from shatter cracks, so I think most of their 34 percent type 2 failures are detail fractures from shelling.

The writer had the privilege of an inspection trip to the British Iron and Steel Research Association Laboratories at Battersea where fundamental research is in progress. Also, a trip was made to Cambridge University where we visited the metallurgy laboratories.

Meetings in Dusseldorf, Germany

In Dusseldorf, one paper was on the Manufacture and Service Performance of Rails, by W. Janiche of Rheinhausen Steel Works. Following is an outline of this paper:

1. German railroads have not been allowed to modernize all of their lines since the war.
2. Their largest tonnage of new rail is of the section S49, which weighs 73 lb per yd.
3. Three years ago a new section S64, weighing 128 lb per yd, was developed.
4. In the period 1925 through 1944 about 90 percent of the rails for German railroads were manufactured from basic Bessemer steel and 10 percent were from open-hearth steel.
5. By developing a new method of roll design the number of longitudinal cracks in the rail base has definitely diminished.
6. Rails of the standard quality 73-lb section are not control cooled.
7. The naturally hard-wear-resistant rails, however, are control cooled in a manner similar to American standards.
8. Because of the high demands on the straightness of the rails it is not sufficient to straighten them only on gag presses. Therefore, the straightening is done in great roller straighteners, with the precaution that excessive stresses are avoided. Only the rail ends, which cannot be gripped by the rollers, must be straightened with a gag press.
9. Continuous welded rail has made great progress in Germany. At the end of 1953 there were 1200 miles of welded track; 4,000,000 joints have been welded by electric flash butt welding and 1,500,000 by the thermit process. Statistics show that up to 1953 only 0.003 percent of all flash butt welded rails had failed and 0.018 percent of the thermit welds had failed.
10. End hardening of rails as frequently employed in America has not met with our approval, especially as several investigations did not yield clearly positive results.

11. Rail failures have also been studied by a subcommittee on rails. It should be remembered that many rails in track are 20 to 30 years old.
12. Web cracks at the bolt holes have accounted for 70 percent of all failures. They can be called corrosion fatigue cracks which start from the bolt holes.
13. One defect, which is also observed in America, the so-called black or shelly spot, has given rise to extensive investigation by the rail subcommittee.
14. On the basis of tests, the conclusion has been drawn that at first a fatigue crack forms in the region of the maximum stresses below the tread, which later proceeds to the gage side.
15. Inhomogeneities of the structures, non-metallic inclusions, etc., can constitute the cause of such fatigue cracks under very high service demands.
16. Another phenomenon which has been studied for many years is corrugation, which is also observed in America, but to a lesser extent. According to extensive investigations, a large number of factors must be held responsible for corrugations. A test track has been laid out, but it is too early to report on the results of observations.
17. The Federal German Railways have put in service grinding trains to remove corrugation, which have given satisfactroy performance.
18. In concluding his report, Mr. Janiche said that, in his opinion, the present rail steels completely meet the demands of the railroads. He asked for greater standardization both on steels for rails and on rail sizes.

There were inspection trips to both laboratories and steel plants in Germany but rails were not being rolled at the time of our meetings.

Meeting in Belgium

On Monday, June 13, the metallurgists went to Liege, Belgium, for a one-day meeting and inspection. The writer visited the new laboratories of the Center National de Reserches Metallurques, which has a comparatively small but very well equipped laboratory in Liege.

Meetings in France

In Paris the meeting feature most interesting to the writer was a three-part paper on The French Thomas Steel Rail, by Messrs. Colnel, Palme and Borione. Mr. Colnel covered the basic convertor steel making and rolling practice. Standard lengths in France are 18 m (59 ft), and 24 m (79 ft). Bolt holes are drilled, and then milled on the inner surfaces, thus eliminating the work-hardened surface. Through this procedure it has been possible to minimize substantially fractures originating from bolt hole cracks.

Mr. Palme, whose laboratory I visited the following day, is in charge of the Subdivision of Rails of the French National Railroads, 50 Rue de Alsace, Paris. His part of the paper covered rail inspection, utilization and service behavior.

Data on French National Railroad System

According to Mr. Palme, the French railroads operate 25,215 miles of track. Some lines have heavy freight traffic, as the Charleville–Thronville line, which has a daily freight traffic of 45,000 metric tons in one direction and 35,000 metric tons in the other. The freight cars have 18 to 20 tons per axle, and speeds range from 37 to 46 mph. Steam engines have axle loads of 21 metric tons and 4931 hp. One type of electric engine has 22 metric tons per axle, but in a new high-speed electric locomotive the axle load has been reduced to 17 metric tons per axle. The horsepower of the electric locomotives is 5326 when based on a one-hour operation; 4830 in normal continuous work-

ing condition. Electrified lines amount to 10 percent of the track mileage, but bear 30 percent of the traffic. The speed of electric passenger trains on the 318-mile run, Paris to Lyon, averages 76 mph, and on the 316-mile run, Paris to Bordeaux, 70 mph. Movies were shown of special test runs with specially geared electric locomotives, which reached a speed of 205 mph.

The Thomas Steel Rail

Continuing, Mr. Palme said: Safety is the first concern of the railroad engineer and he cannot permit the use of poor quality rails. The rail must form simultaneously a beam and runway; it must be easily weldable and have excellent impact resistance. Since it must remain a relatively cheap item, this limits the choice in possible solution from the metallurgical standpoint. It means that the rail in a modern railroad system remains one item on which research can never cease by either the track or steel engineers, and nothing which pertains to this field can be left to chance.

From here on Mr. Palme's paper is reproduced from the translation furnished at the meeting, as I believe most railroad and steel mill engineers will be interested in it.

SPECIFICATIONS

Technical Specifications

Properties generally required of the rails are defined by technical specifications.

The French Standard Specification (Technical Specification 523), which was in use up to April 1954, gave much importance to the physical tests. Chemical analyses were performed only for information. It was considered that the desired results were given by the mechanical tests alone, and that the conditions for this end, principally steel analysis, were to be left to the supplier's decision. On the other hand, conditions regarding steel homogeneity and impact resistance were very exacting. This was why a macrographic inspection, together with a very special impact test (notched bar test), had been specified. This test is very severe, and it has been observed that some imported rails produced from heats which had successfully undergone tests provided under some foreign specifications could not very often stand the notched bar test.

Also to be noted is that the quantity of test is materially stronger and that size tolerances are stricter than provided by most foreign specifications.

Standardization of the technical specifications covering rail supplies

Under the supervision of the Union Internationale des Chemins de fer—UIC—(International Railroad Association), an International Standard Specification was prepared for rail and came into force in April 1954.

The main departure of the new International Standard Specification from the former French specification concerns the impact test applied on unnotched test pieces.[1] The macrographic examination has been maintained. A fact which is worthy of note is that no differentiation has been established between Siemens–Martin, Thomas and Bessemer steels, except regarding analyses and tensile strengths.

[1] The UIC is, on the other hand, presently preparing an impact test on notched test piece with simultaneous recording of the fracture energy.

FRENCH RAIL SECTIONS AND WEIGHTS

The standardized French sections are of the following weights:

46	50	55	kg/m
90	101	111	lb/yd

The 46 and 50 kg/m profiles are used for standard tracks and the thick-web 55 kg/m profile is used exclusively in tunnels.

The new sections, presently being investigated by the UIC (55 and 60 kg/m) with a view to standardization of the European rail, offer a sensible balance between the flange and head masses so as to do away with the camber occuring during cooling and consequently reducing straightening operations to the minimum.

This improvement of the section masses distribution also has the advantage of increasing the moment of inertia.

BOLT HOLE DIMENSIONS

Bolt hole drilling is one of the critical operations in rail manufacture. It is within this area that an important percentage of deteriorations and fractures show up under operational stresses.

Numerous and varied tests have proved that a reduction of bolt hole I.D. (inside diameter), even slightly, would very much improve resistance to crack formation.

These are the reasons why the I.D. has been reduced from 32 mm (1 17/64 in) to 23 mm (29/32 in). Thanks to this measure, bolt hole cracks have become much less frequent.

RAIL BAR LENGTHS

Rails are generally 18 m (59 ft) long,[1] since this length has proved to be the most propitious to their service life.

(Weather conditions in France are relatively moderate and without important temperature difference. The 18-m rail does not require large joint gaps).

WELDED LONG RAILS

The presence of joints in a track rail undoubtedly causes additional heavy maintenance. Rail joint conditions are, in fact, the main life factor of the rail. The SNCF[2] have thus been led to use long rails assembled by welding.[3] Up to now, 1600 km (994.19 miles) of rails on trunk lines of various importance are of the welded type, and future programs provide for an extension of the procedure (800 km, or 497.09 miles in 1955). Special expansion devices take up rail expansion.

Of course, the disappearance of the conventional joint as the result of the welding process has only been made possible by using rail fastenings capable of elasticity, allowing for a constant rail-sleeper cohesion.

In this type of track rails, new added stresses, due to contraction of the steel in cold weather, add to the normal operational stresses, which are thus doubled. To withstand such conditions the rail must be without any surface defects, and

[1] Sometimes 24 m (79 ft)

[2] Société Nationale des Chemins de fer Français.

[3] Generally 800 m (2624 ft)

especially so regarding the flange. It is particularly interesting to acknowledge that the French Thomas steel rails, produced by the "V" shape cutting of the bloom (Keilformiger Einschnitt), have offered excellent results under these conditions.

RAIL WELDING

Two procedures are employed:

1. Electric flash welding, performed in specialized workshops with automatic equpiment.

Thousands of such welds are made every year.

2. The thermit welding process is, on the contrary, carried out on the site. It has been very much improved and simplified during the last 20 years and is widely used on account of the ease with which it is applied.

These methods have made possible the re-utilization of old rails, after being cut to new lengths and welded, and also the joining together, with excellent results of worn rails or rails of different profiles. Generally, 72 to 288-m (236 to 945 ft) lengths are shop welded, to be further welded together in tracks by the thermit process.

From these brief comments can be drawn the conclusion that the welding techniques have now been well perfected and that the rail steel used is perfectly weldable, whatever the process.

RAIL DEFECTS

Rails can show various defects, which are almost identical in all railroads of the world. The most common of these, or the most dangerous, will be commented on in the following, with indications as to the precautions taken in France to cope with them.

1. Fractures in bolt hole zone.

Recurrence of this kind of fracture has already been reduced by substituting the 23-mm (29/32-in) for the 32-mm (1 17/64-in) I.D. hole. An additional improvement is supplied by milling the bolt holes, after rolling, by means of a special milling drill.

As an example, in the case of a plant which for the past 15 years has been manufacturing by this process, approximately 60,000 metric tons have, up to now, recorded only 2 fractures in the bolt-hole zone, which is considered an excellent record.

The long welded rail represents another complete cure against this kind of failure.

2. Internal transverse cracks.

This defect, a serious one since several fractures may happen simultaneously within the rail, is to be found more frequently in Siemens–Martin quality rails than in the Thomas quality rails.

As a precaution against what could result from this kind of failure, we have started to make use of mobile testing equipment (electromagnetic and supersonic), in a systematic check of those tracks carrying the heaviest traffic. During the two years' check carried out, the average of transverse cracks detected was 1 per 13 km (8.07 miles). This figure is substantially the same as found in the United States.

3. Rail batter or flow.

In French tracks this phenomenon is to be observed principally at rail ends. Several processes for hardening rail ends have consequently been investigated, all of them consisting of hardening the rail, either in the shop or in track, with fluids such as water, compressed air, etc.

An induction heating device for rail end hardening is also in use. The reshaping of worn rail end heads is also practiced by electric welding.

4. Fractures and failures originating from segregation .

Such failures have practically disappeared since standard specifications have provided for macrographic tests.

Just as a reminder, let also be mentioned the base seams liable to turn into transverse fractures—now seldom encountered since the new "V" cutting pass of the bloom was adopted.

As the result of these serious efforts, almost all the main types of rail failures have been eliminated.

STATISTICAL RESULTS

In most railroad matters, statistical figures have to be accepted with some suspicion because of the numerous factors—variable in each case—which alter possible comparisons between two different railroad systems. However, some figures are offered in the following since there is no other basis for opinion.

The French figures are taken from the official statistics we send each year to the Ministere des Travaux Publics et des Transports (Public Works and Transport Administration). They show for 1953, 3.8 fractures per billion ton/kilometers.

Foreign figures, must be taken from the last UIC statistics which, unfortunately, are rather old, being prewar. The following figures are to be found for the above referenced period when they were issued:

Great Britain: 2.5 to 5.92 (according to the railroad companies) average 4.2.

France: 2.75 to 12.5 (according to the railroad companies: the French National Railway system had not yet been established at that time)—average 7.6.

Germany: 5.8.

Belgium: 9 to 10.

Spain: 0.679 to 220 (several companies existing at the time).

The average figure in 1939, just after the creation of the SNCF was, for France, 6.2. When this figure is compared to the present one of 3.8, it emphasizes the importance of the developments achieved in improved maintenance methods and the metallurgical factors.

Presently, as far as can be known in the absence of official statistics, we are of the opinion that French railroads can compare favorably with the best European railroad systems.

PRESENT TRENDS

Regarding rail section profiles, there is a trend toward the adoption of a better balanced profile. As already stated, a European standardization of rail profiles is under way; it is also to be added that investigations of this kind,

by the SNCF, increasingly call for scientific methods, and that we proceed with inspections of rail in track with the help of strain gages, piezoelectric quartz devices, and crackling of photoelastic varnishes.

Regarding the quality of steel, constant improvement has been realized during the last 20 years under the instance of the Commission Mixte des Rails (Joint Commission for Rails), established in 1925.[1] This commission, composed of SNCF engineers and rail manufacturers, to which were joined recently representatives from the very important Institut des Recherches de la Siderurgie (Research Institute for the Iron and Steel Industry), investigates the problems arising from rail manufacturing. It has at its disposal the laboratories of the various members of the commission, and especially the SNCF rail laboratory, together with the remarkable IRSID[2] laboratory at Saint-Germain-en-Laye, which constitutes the most complete research combination to be found in France for metal researching.

Under this commission's very active impulse, the trend regarding quality is towards an ever growing and detailed investigation of all factors concerned: quality of the rail materials, technical inspections at every manufacturing stage, etc., together with increasing improvement of methods.

The IRSID on its side has undertaken a vast program of research. Some of the projects, of a very general nature, concern the entire French iron and steel industry, while some others, of a more specialized nature, concern the rail field proper. Some information on the latter is given in M. Borione's part of this report.

SUMMARY AND CONCLUSION

From the above it is to be remembered that the rails used by the SNCF—one of the most important in the world measured by its network and traffic—are of Thomas steel (some imported rails after both World Wars and old rails excepted).

These rails, most of them manufactured in compliance with the very strict French Technical Specification No. 523, come today under the International Specification No. 722. Both require outstanding manufacturing practice, and the Thomas rail manufacturing process does, indeed, resort to a combination of precautions which are a guarantee of the quality.

At the same time, the rail in France, as already explained, under the instance of the Joint Commission for Rails, is the object of constant and particularly elaborate researching. In fact, few manufacturing and use problems have not been undertaken. It is mainly through the impulse from this commission that the manufacturing improvements referred to were originated.

From the above it can be stated that it is possible, with complete peace of mind, to trust fully the Thomas rail the way it is manufactured in France for SNCF requirements.

On my visit to Mr. Palme's laboratory I saw failed rails and reports with pictures of failed rails which were similar to our American failures. There were quite a number of detail fractures from shelling, and in general the shelling cracks were deeper in the rail heads than most such failures in American rails. I saw a few failures of welded rails, both electric flash welds and thermit welds, mostly from tunnels.

[1] By the Ministere des Travaux Publics (Public Works Administration)

[2] Institut de Recherches de la Siderurgie (Research Institute for the Iron and Steel Industry).

Rail Corrugation—Can It Be Prevented?

By C. H. Spaderna*

Introduction

One of the most challenging engineering problems of our day is rail corrugation. Railroads are striving for higher train speeds, but at the same time they realize that higher speeds may bring forth undulations 0.01 in deep, that accelerate wear on rails.

The problem appears rather complex and has been widely discussed for 50 years. A complete solution will be reached only as the joint effort of all concerned opens the way for further progress.

The writer is glad to submit the findings of his research, consisting of the establishment of a relation between natural frequencies of rail vibration and wave length of the corrugation. However, his computation of a reinforcing vibration of the axle needs checking by experiment. Should it prove correct, corrugation could be eliminated by axle redesign as well as by changes in rail profile and tie spacings.

Spacing of Ties

The author found a "predominant frequency" f among the vertical rail vibrations showing outstanding accelerations. It shifted with the ties spaced at another distance. Therefore, it was concluded that a resonance effect picked out the predominant frequency. The natural frequencies of bending vibration of the rail were recorded. These frequencies are, in cps:

$$f_i = \frac{k^2_i}{d^2} \sqrt{\frac{EI}{sF}} \qquad (1)$$

in which $E =$ modulus of elasticity $= 2.1 \times 10^6$ kg/cm^2; $I =$ moment of inertia of the rail, referred to its horizontal axis, in cm^4; $i =$ ordinal number 1, 2, 3, 4, 5, etc.; $s =$ specific gravity $= 7.5$; $F =$ cross section of rail in cm^2; $d =$ distance between center lines of ties $= 65$ cm in most of Western Europe, but $d =$ about 19.5 in $= 49.5$ cm in America; $k^2_1 = 22.35$; $k^2_2 = 61.7$; $k^2_3 = 120.9$; $k^2_4 = 198.5$; $k^2_5 = 297$. Further constants are of little interest.

Computed and measured frequencies are compiled in Table 1.

For ASCE 90-lb rail a predominant frequency, $f = 320 \pm 8$ cps, was found. A resonance of 2 upper harmonics of natural frequencies f_1, f_2 was computed: $11 \times f_1 = 314$ cps, $4 \times f_2 = 314$ cps. This method of matching common multiples of f_i against measured frequencies proved even more accurate on European tracks, including narrow gage railroads.

The traveling distance covered by rapid trains during $1/f$ sec could be reconciled with the average wave length r of corrugation. Thus $r = v/f$, with the velocity v in cm/sec, gives 3 in. in America, 1.8 in. in Europe.

---

* The author is a graduate of the German Technical Institute of the University of Prague, who during World War II was employed by the German State Railways and later connected with the German State Railways Research Institute at the University of Göttingen, Germany. Here he was engaged in vibration studies pertaining to railroad roadbed with concrete ties, and correction of tracking characteristics of American 2-axle trucks over German switch installations. He is now residing in Worcester, Mass. He is the author of two previous papers on "The Origin of Rail Corrugations", and "Ways to Prevent Corrugations", both published in Vienna.

The Making of Rail Corrugation

The troughs of rail corrugation showed unexplainable holes. Even the smallest wheels could not be pressed into these holes at the bottoms of ripple valleys. If corrosion were responsible, it could not be explained why the crests stood up so well. However, the author measured accelerations of 100 *g* and more on European rails S 49 ($g = 981$ cm/sec^2 accelerations of gravity in the cm g sec system). This frequent bending could well cause fatigue of the rail surface layer, and wheel hammering could split away particles of the size of the holes. In fact, the author witnessed a flying particle hitting his instruments.

Some vibration, x, of the mounted axle and the predominant frequency, f, of the rail obviously reinforce each other until the high acceleration is reached. It follows from the quickness of their appearance in each new field between neighboring ties that the timing resonance of x and f must be close. Sometimes they will fall out of step, causing a shock. An important factor entering into the problem is the wave length l of rail vibration. Unfortunately, this factor could not be determined accurately but was estimated to be not much longer than $r = 4.5$ cm = about 1.8 in, the wave length of ripples in Europe. This guess was in perfect keeping with the fact that rail acceleration went up with the speed of trains beyond the average speed of 55 mph. Obviously, resonance is not yet at 100 percent. Should the speed of trains be increased in years to come, l might match r, and still deeper corrugation would result. However, beyond this resonance, speed relief may be expected.

The f_1 frequency reached accelerations of about 2 *g* at 15 cps and may be neglected in comparison to the more than 100 *g* of frequency f. This accounts for the even shape of the ripples all over a field.

The Probable Co-Producer of Corrugation

Which vibration, x, of the mounted axle is the probable co-producer of corrugation? By design, x could be eliminated if it were known, thus ending the mutual aid of x and f. Also, that would mean the end of corrugation.

It proved difficult to measure axle vibrations while the axle is rolling. However, on a vertical axle, with one wheel fixed to the ground and the other wheel replaced by a spinning eccentric weight, conditions were simulated. Blows with a heavy hammer caused vibrations lasting for several revolutions of the eccentric—at high speed of course. These hammer vibrations were picked up near the wheel by strain gages.

The mechanism of probable vibration, x, is illustrated in Figs. 1 and 2. As the journal axle A is steadily bent downward by the weight on box B, the journal appears clamped at both ends. The vibration, natural to this situation is, after a known formula:

$$x_1 = \frac{3.55}{l^2} \sqrt{7.01 \times R^2 \times 10^4} \qquad (2)$$

in which l = length and R = radius of the journal in cm. Further natural frequencies, x_2, x_3, x_4 and x_5 are obtained from x_1, multiplying it by 2.763, 5.39, 8.88 and 13.3, respectively. Results for various axles are compiled in Table 2.

Conclusions

1. It should be possible to find dimensions of the journal axle which give no x resonant with f in time. A theoretical journal of that property is shown at the end of Table 2.

(Text continued on page 311)

TABLE 1 - VIBRATION OF RAILS AND CORRUGATION DATA

Profile	Mean spacing of ties, d in cm, measured	Measured predominant frequency, cps	Computed predominant frequency, cps	Computation of predominant frequency f in cps.	Mean spacing of corrugation, r in cm: measured	Computed v/f	actual v, mph
ASCE-90 America	45.7 = 1.5 ft	320 ± 8 secondary track	314	11 x f_1 = 314 4 x f_2 = 314	7.6 = 3 inches	7.7	54.4
AREA-115 America	49.5 = 19.5 in	main track	327	11 x f_1 = 326 4 x f_2 = 328	7.6 = 3 inches	7.65	56.0
AREA-100 America	49.5 = 19.5 in	300 ± 8 secondary track	298.5	11 x f_1 = 298 4 x f_2 = 299	7.6 = 3 inches	7.6	50.0
S 49 Central Europe	55 = 21.6 in	520	521	25 x f_1 = 522 9 x f_2 = 520		4.7	~ 55
	60 = 23.6 in	316	314.5	18 x f_1 = 316 2 x f_4 = 313		7.7	~ 55
	65 = 25.6 in	535	535.7	13 x f_2 = 538.2 4 x f_4 = 533.2	4.5 - 4.7 = 1.78 - 1.85 in	4.5 - 4.7	54.4 - 56.0
	70 = 27.6 in	580	570	44 x f_1 = 570 16 x f_2 = 570		4.2	~55
	75 = 29.5 in	600	599.5	6 x f_4 = 600 4 x f_5 = 599		4.0	~ 55
"NP4"	65 (1 m gage)		660.5	13 x f_2 = 661 4 x f_4 = 660	1.5	1.5	22.5
"6"	65 (1 m gage)		157	13 x f_2 = 157.3 4 x f_4 = 156.8	4-5	4-5	14.5 - 18.0

TABLE 2 - VIBRATION OF THE AXLE

Designation of Axle	Journal Axle, Hub Length, cm	Journal Axle, Hub Radius, cm	Computation of axle frequency x, in cps.	Computed axle frequency x in cps	Predominant Frequency of Rail resonant with axle frequency Main Track	Predominant Frequency of Rail resonant with axle frequency Secondary Track
A	17.8 = 7 in	4.76 = 15/8 in	$8 \times f_2 = 8 \times 39.25$	314		314
			$4 \times f_3 = 4 \times 76.5$	306		300
B	20.17 = 8 in	5.4 = 17/8 in	$3 \times f_4 = 2 \times f_5 = 334$	334	327	
			$9 \times f_2 = 9 \times 32.68 = 312$	312		314
C	22.86 = 9 in	6.3 = 2.5 in	$10 \times f_2 = 10 \times 31.5 = 315$	315		314
			$3f_4 \sim 2f_5 = 304$ }	305.5		300
			$5 \times f_3 = 5 \times 61.4 = 307$ }			
D	25.4 = 10 in	6.98 = 2.75 in	$6 \times f_3 = 6 \times 54.8$	329	327	
			$11 \times f_2 = 11 \times 28.07$	309		300
E	27.94 = 11 in	7.62 = 3.0 in	$4 \times f_4 = 4 \times 81.5$	326	327	
			$6 \times f_3 = 6 \times 49.4 = 296.5$ }	299		300
			$12 \times f_2 = 12 \times 25.15 = 302$ }			
F	30.5 = 12 in	8.25 = 3 1/4 in	$14 \times f2 = 14 \times 23.2$	325	327	
			$13 \times f_1 = 13 \times 23.2$	301		300
			$7 \times f_3 = 7 \times 44.9$	314		314
Central European Standard	20.0 ≅ 7.88 in	5.75 = 2.26 in	$3 \times f_5 = 3 \times 179.7$	539	535	
			$40 \times f_1 = 40 \times 13.5$	539	535	
Proposed for main tracks, AREA - 115 rail.	25.4 = 10.0 in	7.62 = 3.00 in	$3 \times f_4 = 3 \times 99.0$	297		300
			$2 \times f_5 = 2 \times 148.5$	297		300
			$5 \times f_3 = 5 \times 60.0$	300		300

2. From equation (1) it can be seen that frequencies f_1 will be lower with a smaller ratio I/F. That means that rails with a broad base have slower natural vibrations, usually resulting in lesser accelerations. Thus, less hammering force is developed.

3. Shorter spacing of ties is to be preferred as they produce low f_1 (Table 1). An exception is 55 cm = about 22 in, which should be avoided.

References

1. Wege zur Verhütung der Schienenriffel (How to Prevent Rail Corrugation), by the same author, in "E and M" Vol. 72, No. 1, 1955, Vienna, Austria.

2. Wodurch entstehen Riffeln? (What Causes Corrugation?), in VDI, Zeitschrift, Vol. 97, No. 13, May 1, 1955, pp. 404–405, Dusseldorf, Germany.

3. Das Ratsel der Riffeln auf Eisenbahnschienen (The Riddle of Rail Corrugation) in Glasers Annalen, Vol. 79, No. 2, February 1955, Berlin, Germany.

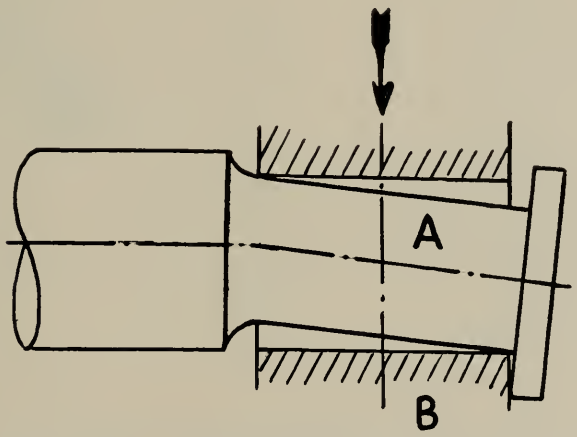


Fig. 1—Exaggerated relative position of moving journal axle, A, and journal box, B.

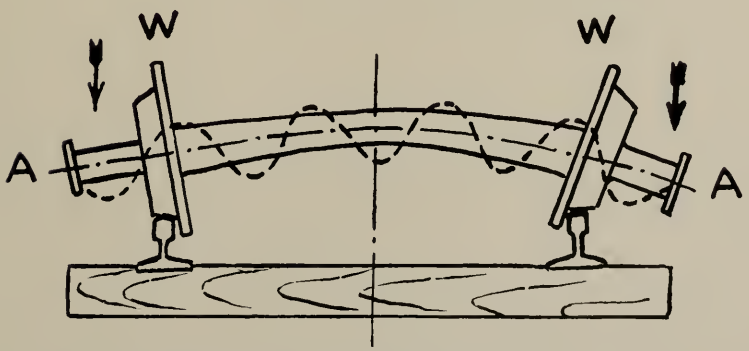


Fig. 2—Exaggerated vibration waves of journal axles, A, and wheels, B.

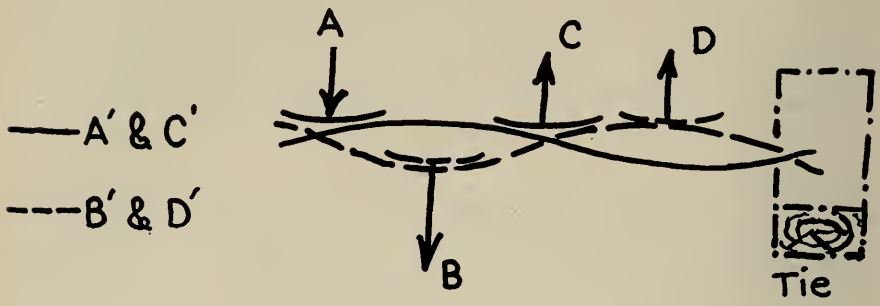


Fig. 3—Vibrations of rail and mounted axle.

A, B, C, D: positions of wheel and rail corresponding in time.

Report of Committee 16—Economics of Railway Location and Operation

H. B. CHRISTIANSON, JR., *Chairman,*

R. L. MILNER, *Vice Chairman,*
C. W. SOOBY, *Secretary,*
HERBERT ASHTON
Q. K. BAKER
J. W. BARRIGER
J. W. BARRIGER, IV
J. M. BENTHAM
C. H. BLACKMAN (E)
J. W. BOLSTAD
I. C. BREWER
D. E. BRUNN
F. J. CORPORON
R. R. CRANE
J. W. DEMCOE
MISS OLIVE W. DENNIS (E)
J. M. FOX
R. A. GLEASON
W. J. HARLOW
ALLEN HAZEN
C. L. HEIMBACH
H. C. HUTSON
J. E. INMAN
C. A. JAMES
J. E. JAY
R. J. D. KELLY
W. S. KERR
H. A. LIND
A. E. MACMILLAN
F. C. MCNEILL
R. B. MIDKIFF
M. B. MILLER
H. P. MORGAN
F. N. NYE
F. B. PETER
C. W. PITTS
E. C. POOLE
W. E. QUINN
J. P. RAY
W. T. RICE
C. P RICHARDSON
C. P. RICHMOND
E. H. ROTH
GEO. RUGGE
A. L. SAMS
P. J. SCHMITZ
H F. SCHRYVER
H. M. SHEPARD
L. K. SILLCOX
R. F. SPARS
D. S. SUNDEL
J. E. TEAL (E)
G. H. TILSON
C. L. TOWLE
D. K. VAN INGEN
L. E. WARD
H. P. WEIDMAN
T. D. WOFFORD, JR.
H. L. WOLDRIDGE
J. A. WOOD
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report. (For Manual recommendations, see report on Assignment 3)

2. Cost of track curvature.
   Progress in study, but no report.

3. Revision of Yager formula, collaborating with Committee 11.
   Progress report, with recommendations submitted for adoption ..... page 314

4. Economics of "highway trailers on flat cars" service, collaborating with American Association of Railroad Superintendents.
   Final report, presented as information ..... page 314

5. Comparison of running time with total time between loading and unloading points of freight cars, and method of reducing total time, collaborating with Car Service Division, AAR, Signal Section, AAR, Communications Section, AAR, and American Association of Railroad Superintendents.
   Progress report, presented as information ..... page 321

6. Economies of improved freight stations and facilities, collaborating with Committees 6 and 14, and with Freight Station Section, AAR.
Progress in study, but no report.

7. Life of rail, collaborating with Committee 4.
Progress in study, but no report.

8. Innovations in railway operations.
Progress in study, but no report.

COMMITTEE ON ECONOMICS OF RAILWAY LOCATION AND OPERATION,
H. B. CHRISTIANSON, JR., *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 3

Revision of Yager Formula

Collaborating with Committee 11

J. P. Ray (chairman, subcommittee), H. B. Christianson, Jr., J. M. Fox, J. E. Inman, R. L. Milner, H. A. Lind, E. C. Poole, H. M. Shepard, C. L. Towle, D. K. Van Ingen.

This is a progress report with recommendations that certain material in Manual, be withdrawn.

Your committee is studying the Method for Determination of Proper Allowance for Maintenance of Way Expense Due to Increased Use and Increased Investment, which appears in Manual, Chapter 16, pages 2–13 to 2–18, incl. (This method has become popularly known as the "Yager" formula.)

Our study of the effect of use on maintenance of way expenditures is progressing and in the course of such investigation it has become evident that the "Yager" formula is unacceptable for present-day conditions. Your committee anticipates the submission next year of an up-to-date formula. In the meantime, to guard against the use of data which has been outmoded, Committee 16, by letter ballot, overwhelmingly recommends that the formula now appearing in Chapter 16, pages 2–13 to 2–18, incl., be withdrawn.

Report on Assignment 4

Economics of "Highway Trailers on Flat Cars" Service

Collaborating with American Association of Railroad Superintendents

F. N. Nye (chairman, subcommittee), Q. K. Baker, J. W. Barriger, W. J. Harlow, J. E. Jay, E. C. Poole, W. E. Quinn, L. K. Sillcox, P. J. Schmitz, H. M. Shepard, D. S. Sundel, C. W. Sooby, G. H. Tilson, C. L. Towle.

Your committee last year presented an introductory report (Proceedings, Vol. 56, 1955, page 334) giving the background of trailer-on-flat-car operations, its current development, and some basic legal, traffic and competitive considerations. As to the economics of such a service, the report stated:

> Each railroad considering such an operation must evaluate the potential revenues in terms of its own direct operating expenses—both line haul and terminal—and the cost of providing and maintaining the specialized equipment and terminal facilities. These costs must be further considered in the light of motor carrier, direct over-the-road costs in the same territory. This will develop a 'zone of negotiation' for an agreement as to divisions where joint operations are contemplated. Its traffic officials must evaluate the availability of traffic—whether under rail tariffs or under joint arrangements with motor carriers—and whether or not the attracted traffic will become a permanent part of the operation or merely a service of convenience to the highway operators.

In this concluding report we deal further with the economics of the service, which essentially involves a comparison of prospective and potential revenues with the estimated costs—both out-of-pocket and fully distributed—of conducting the operation. As to the probable revenues, that is a matter for a railroad's freight traffic department to develop. It will depend on the anticipated volume of trailer business under the published tariff rate—which of necessity must be fully competitive with prevailing motor carrier rates and charges if the service is provided with railroad-owned trailers and handled on a store-door basis by railroad terminal tractors.

If handled jointly with motor common carriers which provide the trailers and perform the terminal distribution, the anticipated railroad division of the motor carriers' published tariff rate would generally be a flat charge per loaded trailer, predicated on a slight undercutting of the motor carriers direct line-haul costs.

Against these anticipated revenues the railroad must weigh its estimated cost. Cost determinations on a railroad—confronted increasingly with both highway and waterway competition—must of necessity become of controlling importance. The old value-of-service theory will in the future, we believe, be forced to a secondary status. Competitive rates as published today are frequently subject to protest by the "aggrieved carrier" and are often suspended by the Interstate Commerce Commission. To justify them before the commission it is essential to prove them compensatory, at least on an out-of-pocket basis, and to show further that they make some contribution to overhead or fully distributed costs. If a railroad defendant is not prepared to submit forthright and logically constructed cost figures, the commission or the protestant will rely on statistical data and methods of a complicated and confusing nature, which will prejudice and perhaps defeat the railroad's legitimate effort to meet its competition.

Cost finding is a difficult procedure—and perhaps a dangerous business—but railroad management can not evade its responsibility honestly and aggressively to meet its competition and to do so at a profit. It is better, we believe, to prepare freight costs in the light of actual experience and with an understanding of the proposed operation, than to have the opposition becloud the issue by alleging costs which are compounded from system-wide averages predicated on all services—both freight and passenger.

In conducting the operations of an entire railroad all costs must ultimately be protected, but in pricing a new and particular service—to meet competition—the expenses can and should be divided between direct or out-of-pocket costs and indirect or fully distributed costs. In the following analysis, the line of approach is to develop the added cost for an increment in traffic, i.e., a train of flat cars carrying highway trailers between two predetermined termini. Such direct costs, of course, may vary from time to time as the direction and volume of traffic over the system or over a division may change and so affect the balance of operation and unit costs. The factor of unused capacity must always be considered—costs increase only moderately until capacity is reached, then they may rise rapidly unless capital expenditures are made to increase capacity.

Consider a proposed operation between the two major cities, A and B, located 300 miles apart—a distance highly susceptible to motor carrier competition—between which the freight traffic department believes it can develop a revenue movement of 100 trailers in each direction 5 nights a week, provided an assured schedule can be provided with a 10:00 pm departure and a 6:00 am arrival.

Assume that the railroad's management has confidence in the ability of the traffic department to produce this business—without jeopardy to its carload rate structure—and is confident that the scheduled service accorded will retain it. They therefore place an order for a fleet of 70-ft flat cars, especially adapted to end-load and tie down of 2 trailers per car. A 50-car train will move nightly in each direction, and, allowing some leeway for maintenance and repairs, a pool of 110 cars is provided.

Assume that a 3-unit diesel can handle each train at an average speed of 40 mph—with an intermediate stop to change crews and inspect equipment—and so provide an assured scheduled service.

Assume further that an end loading terminal can be provided at a cost of $250,000 at each city ($150,000 for construction on land worth $100,000).

The cost for the proposed operation, the committee believes, can be approximated as follows (all figures shown are hypothetical and must be developed from records on each road making such a study):

Direct Cost Per Train Mile

1. *Maintenance of Running Tracks*

Consult annual report Form A to the ICC, and draw off freight portion of M. of W. accounts for ties, rail, other track material, ballast, track laying and surfacing, roadway machines and tools and supplies, and divide total by freight car miles operated during year—assume that this unit cost is about 2.0 cents.

2.0 cents × (50 cars plus caboose) $1.02

2. *Maintenance of Loading Tracks and Switches, Loading Ramps, etc., at Terminals*

This will consist principally of cleaning, snow removal and light spot maintenance. A 4-man gang normaliy available at proposed terminal sites can perform the necessary work in, say, 1 day per week:

$$\frac{4 \text{ men} \times 8 \text{ hr} \times \$1.75 \times 2 \text{ terminals}}{600 \text{ train miles/day} \times 5 \text{ days/week}} \quad \ldots\ldots 0.04$$

Note: It is assumed that the trailer-on-flat-car trains will be "main tracked", so no maintenance-of-way costs at intermediate yards are involved.

3. *Maintenance of 3-Unit Freight Diesel Locomotive*

A 51-car train will weigh about 4000 tons and probably require—depending on physical characteristics of line—a 3-unit diesel to meet rigid schedule. Obtain from Mechanical Department the following costs, say:

Running repairs ..... $0.60 per mile
Shop repairs 0.15
Total $0.75 ..... 0.75

4. *Maintenance of Special 70-Ft Flat Cars (and Caboose), Incl., Inspection and Lubrication*

Obtain costs from Mechanical Department, say
$0.025 × 51 cars 1.28

Direct Cost Per Train Mile

5. *Diesel Fuel, Lubricants and Supplies*

Obtain the following from Mechanical Department:

Fuel	about $0.70
Crankcase oil	.03
Other oil and grease	.02
Supplies	.01
Total	$0.76 ..... 0.76

6. *Enginehouse Expense*

Obtain from Mechanical Department, say 0.18

7. *Engine and Train Crew Wages*

Use crew and standard rates of pay based on agreements:

Engineman	about 18.0	cents per mile
Fireman	16.0	" " "
Conductor	15.0	" " "
Head brakeman	13.0	" " "
Rear brakeman	13.0	" " "
Total	75.0	0.75

Note: If constructive mileage is involved, provision for it must be made.

8. *Switching at Trailer Terminals, Including Coupling, etc.*

Note: This is the only switching involved because proposed trains are to be main tracked between terminals.

Yard Crew, based on wage agreements:

Engineman	about $ 2.20	per hr
Fireman	1.95	" "
Conductor	2.20	" "
Brakeman (2)	4.20	" "
Total	$10.55	

Locomotive Costs (from Mechanical Department)

Fuel, lubricants and supplies Enginehouse expenses and maintenance	3.50	per hr
	$14.05	" "

Allow 2 hr at each terminal, for inbound arrival and also for outbound departure:

$$\frac{4 \text{ hr (arrival and departure)} \times \$14.05 \times 2 \text{ terminals}}{600 \text{ train miles per day}} \quad \ldots\ldots \quad 0.19$$

9. *Cost of Circus-Style Loading and Unloading Trailers, Inspecting Tie-downs etc.*

Allow about $2.50 per handling at origin and again at destination:

2 trains with 100 trailers each:

$$\frac{200 \text{ trailers per day} \times 2 \text{ handlings each} \times \$2.50}{600 \text{ train miles per day}} \quad \ldots\ldots \quad 1.67$$

	Direct Cost Per Train Mile
10. *Billing and Station Accounting*	
Two clerks at each of 2 terminals at $16.00 per day approximates:	
$\frac{\$64.00}{600 \text{ train miles per day}}$	0.11
Total direct or out-of-pocket assignable operating expenses—line haul and terminal—per train mile	$6.75
Allow approximately 15 percent for superintendence, overhead, payroll taxes, etc.	1.00
Total, excluding capital charges and return on investment	$7.75

Note: No specific provision is made for loss and damage, as experience has shown that these are negligible items.

It will be observed that this simplified out-of-pocket cost estimate consists of a variety of items, some directly estimated and some deduced by statistical methods; it is offered merely as an approximation of the principal involved costs. The solution is predicated on a 50-car train, with 100 trailers, in balanced, loaded movement. During the development stage it would probably operate with fewer cars, at higher unit cost. A time would come when 2 sections might be required, each with perhaps 40 cars. The cost analysis would necessarily be altered to reflect this variation in train length and in loaded occupancy.

In addition to the direct operating expenses and overhead as tabulated above, there are, of course, capital costs for new terminals, special rolling stock and power.

The capital costs for terminals divided into the special train miles, of course, depends on the number of trains each terminal can serve daily. We assume, at least initially, only one train inbound and outbound daily. By staggering arrivals and departures by two or more hours, additional trains might be served between the original two terminals—if volume developed—or from a third terminal on a triangular operation.

We assume that end-loading facilities with adequate parking space will satisfactorily serve at the outset. As business develops the volume may require high-level side-loading platforms to expedite terminal handling and so increase capacity during the critical hours of loading and unloading. The considerable greater cost of side-loading terminals would, of course, be partially offset against the larger throughput.

	Per Year
Capital improvements at terminals are assumed to cost about $150,000 each, or $300,000 for 2	
Land is valued at $100,000 per terminal, or $200,000 for 2	
To write-off improvements over a 15-year period	$20,000
Average value of two terminals' improvements over 15-year life $150,000	
Interest at 6 percent on average book value of improvements	9,000
Interest at 6 percent on land ($200,000)	12,000
Taxes, assessed value 60 percent on improvements $180,000	
full value on land 200,000	
$380,000	
Assumed tax rate ..... 4 percent	15,200
Total capital charges for terminals	$56,200

		Capital Cost Per Train Mile
$56,200 per year / 600 train miles per day × 5 days per week × 52 weeks per year		$0.36

Capital Charges on Special Flat Cars

110 cars at $12,000 each	$1,320,000	
Depreciation at 3.0 percent		$39,600 per year
Average value over life cycle	$ 660,000	
Interest at 6 percent		$39,600
Total		$79,200 per year

$79,200 per year / 600 train miles per day × 5 days per week × 52 weeks per year	0.51

Capital Cost of Providing Two 3-Unit Road Diesels and Cabooses

3-Unit Diesel cost, about	$550,000	
Caboose cost	15,000	
	$565,000	per train
Depreciation at 4.0 percent		$22,600
Average value over life cycle	$282,500	
Interest at 6 percent		16,950
Total		$39,550

$39,550 per year × 2 trains / 600 train miles per day × 5 days per week × 52 weeks per year	$0.51

No capital charge is made for yard power for terminal switching as it presumably is already available.

Note: Locomotives in this service would work only 5 nights per week. Between runs and on weekends they should, where possible, be thrown into the power pool and used on other trains. No credit, however, has been taken. Conversely, no provision has been made for reserve power.

Summary of Operating Expenses and Direct Capital Charges

	Per Train Mile
Operating expenses, + 15 percent	$7.75
Direct Capital Charges:	
End-loading terminals	0.36
Special flat-car equipment	0.51
Assigned power and cabooses	0.51
Total, approximately	$9.13

In addition to the above direct expenses and capital charges a railroad providing a right-of-way equivalent to a toll road or throughway might reasonably expect as a fairly allocated return on its investment in roadway, track and structures the equivalent of the toll charge, which the trailer would pay if operated by a tractor along the toll road, say 2¼ cents per trailer mile.

(Note: A typical toll charge for tractor and trailer is around 4½ cents per mile, divided, say 50 percent–50 percent, between tractor and trailer.)

50 cars × 2 trailers per car × 2¼ cents ..... $2.25 per train mile

Note: If the route includes trackage charges, they should be separately shown.

Grand Total, including return on investment in road, as well as on terminals and equipment, approximately $11.38 per train mile
or 0.23 per flat car mile
or 0.12 per trailer mile

The above analysis, it should again be emphasized, is an attempt at a direct and simple approach to a very involved problem involving joint costs as between passenger and freight service. The later includes through freights, local freights, etc., each carrying a multitude of different commodities in different types of cars with varying tonnages, different degrees as to empty return movement, and in both CL and LCL lots. It must be recognized that in this "formula" fully distributed costs are not protected. If motor carrier direct over-the-road costs in the territory are, say 27 cents per trailer mile, the "zone of negotiation" for a joint coordinated service will range from $0.12 to $0.27. The railroad can not undercut its out-of-pocket costs; the participating motor carrier will not pay more than it costs him to perform his own transportation. If both parties "split" the difference, the agreed charge would be 19.5 cents per trailer mile. In all fairness the railroad is entitled to something more, because its out-of-pocket costs are substantially less than its fully distributed costs—and in the long run these larger costs must be protected. The hypothetical figures used in this report suggest that the railroad should seek approximately $0.23 per trailer mile. This undercuts the motor carrier's cost by 15 percent—a worthwhile inducement.

If the railroad is to hold out its trailer-on-flat car services, with its own motor equipment and under its own tariffs, the "formula" will generally show that truck-competitive rates are compensatory. In certain cases already decided by the Interstate Commerce Commission this has been established.

The committee submits this final report to illustrate one method of evaluating this problem. Each railroad developing cost data for such a service must, of course, rely on its own statistics and apply them in a manner consistent with its physical characteristics and its proposed method of operation.

If the added trailer traffic is to be handled on converted 40 ft flat cars, each with 1 trailer, rather than on new 70-ft flat cars, each with 2 trailers, and if it is to be absorbed on regular trains rather than handled in new solid trains, and if pickups and setoffs are made at many stations, using, let us say, portable ramps, rather than at costly terminals located only at major cities, this operation and its economics would be very different. The solution involving so many variables would then be much more complicated and perhaps inconclusive. In addition, the traffic implications would be different—and the service characteristics would be materially altered.

Report on Assignment 5

Comparison of Running Time with Total Time Between Loading and Unloading Points of Freight Cars, and Methods of Reducing Total Time

Collaborating with Car Service Division, AAR, Signal Section, AAR, Communications Section, AAR, and American Association of Railroad Superintendents

J. E. Jay (chairman, subcommittee), Q. K. Baker, J. W. Barriger, J. W. Barriger IV, J. W. Bolstad, R. R. Crane, J. W. Demcoe, R. A. Gleason, W. S. Kerr, A. E. MacMillan, R. B. Midkiff, E. C. Poole, W. T. Rice, L. K. Sillcox.

This is a progress report, submitted as information.

Summary

Data on the movements of approximately 500 freight cars were collected by AREA Committee 16. In view of the small size of this sample relative to the total number of freight cars, and the difficulty in obtaining this type of data, the question arose as to whether it was necessary to obtain additional data in order to assure the reliability of the results.

This introductory progress report presents the results of an analysis of the AREA data and compares these results with those obtained in the report of the Federal Coordinator of Transportation on "Railroad Freight Transportation", which was published in 1935. The report of the Federal Coordinator was based on a large sample of freight cars, and it was found to agree very closely with the results of the analysis of the AREA data. Consequently, it was concluded that the relatively small sample already obtained was sufficient to illustrate the problem.

A second concusion is that increased emphasis should be placed on improving freight car utilization by working in those areas where AREA data indicate car delays are the greatest.

Introduction

Committee 16 collected data concerning the movements of 495 freight cars with the purpose of finding ways and means of improving the utilization of rolling stock.

The data were obtained by the AREA in reply to letters sent to various railroads requesting information from each railroad on 40 cars, divided into 4 groups of 10 cars each. These four groups were: (1) cars loaded on switching lines and unloaded on reporting line; (2) cars loaded on reporting line and unloaded on switching line; (3) cars loaded on reporting line and unloaded on reporting line; and (4) cars passing overhead, i.e., cars loaded and unloaded off reporting line but traveling part of the way over the reporting railroad.

In nearly all cases the data received contained the following information:

(a) Total time the car spent from time placed for load until released from load.
(b) Time the car was in the shipper's control.
(c) Time the car was in the railroad's control.
(d) Time the car spent waiting at origin and destination.
(e) Time the car spent in intermediate terminals.
(f) Time the car spent in interchange terminals.
(g) Time the car was in trains.
(h) The total distance the car traveled.

Method of Analysis

Various statistics were obtained from this data. The length of time an average freight car spends loaded was determined by averaging the data for all cars for which complete histories were shown. The average time a car spends waiting at various locations, the average distance traveled, and the average speed were similarly determined.

In order to obtain some idea of the validity of the results of the analysis of this relatively small sample, wherever possible the averages computed from AREA data were compared with those published in a report issued in 1935 by the Federal Coordinator of Transportation, of car utilization on December 13, 1933.

Results of Analysis of AREA Data

The following tables and charts show a comparison of the averages from the two sources described above:

Table 1—Average Time A Car Remains Loaded

	Averages	
	From AREA Data	*From FCT Report*
Total time from time placed for load until released from load	167 hr	144 hr
Time in shipper's hands	85	68
Time in railroad's hands	82	76

Table 2—Distribution of Car Time While Car Is In Railroad Hands

	Averages	
	From AREA Data	*From FCT Report*
Time in terminals	63 hr	53 hr
Time in trains	14	23
Misc'l delays	5	Not shown

Table 3—Average Delay Per Car At Terminals

	Averages	
	From AREA Data	*From FCT Report*
Waiting movement at origin	16 hr	11 hr
Waiting placement at destination	16	15
Time at interchanges	7	Not shown
Time at intermediate terminals	24	27

Table 4—Average Haul and Speeds

	Averages	
	From AREA Data	*From FCT Report*
Average road haul	285 miles	376 miles
Speed in trains	20 mph	16 mph
Speed in railroad hands	3.6 mph	2.6 mph

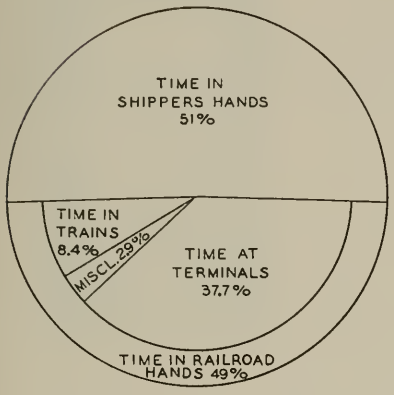
Discussion of Results

Table 1 shows that the average loaded car spends about an equal amount of time in consignee-consignor hands and in railroad hands.

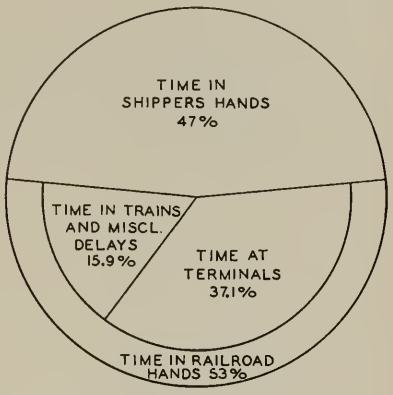
Table 2 indicates that most of the time a car is in railroad hands is spent in terminals waiting to be moved; only 8.4 percent of the total time a car is loaded is spent in road trains.

These tables and accompanying figures show that cars spend considerable time in consignee-consignor hands, and in waiting for placement or line hauls while in railroad hands.

FIGURE 1– ANALYSIS OF LOADED CAR TIME
BASED ON TABLES 1 AND 2

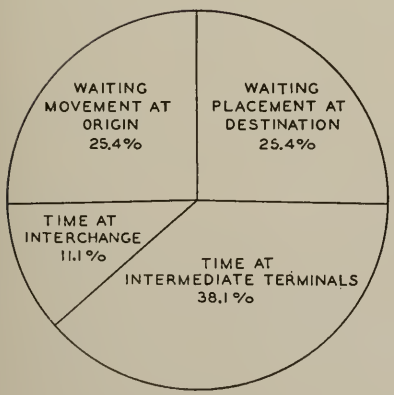


FROM AREA DATA



FROM FCT REPORT

FIGURE 2–ANALYSIS OF LOADED CAR TIME
IN RAILROAD HANDS OTHER THAN
IN ROAD MOVEMENT
BASED ON TABLE 3



FROM AREA DATA

FROM FCT REPORT

There is a close similarity between the averages computed from the AREA data and those obtained from the FCT report of 1935. In fact, the AREA data raise the question as to whether or not freight cars are being utilized as completely now as it was reported they were being utilized in 1935.

Conclusions

The close similarity of the results of the analysis of AREA data and those obtained from the data 20 years ago suggests that the data already obtained by the AREA is sufficient to indicate how cars are being utilized and where effort can best be expended next to increase car utilization effectively.

Report of Committee 9—Highways

W. C. Pinschmidt,
Chairman,

C. I. Hartsell,
Vice-Chairman,
R. W. Mauer, *Secretary,*
H. D. Blake

Bernard Blum (E)
C. O. Bryant
C. M. Carnahan
R. B. Carrington, Jr.
A. C. Cayou
M. H. Corbyn
Raymond Dejaiffe
J. R. Derieux, Jr.
A. D. Duffie
W. R. Dunn, Jr.
P. W. Elmore
E. R. Englert
J. S. Felton
Marvin Gates
S. B. Gill
H. F. Gilzow
R. W. Harrison
Wm. J. Hedley
J. T. Hoelzer
W. H. Huffman
D. W. Hughes
Maro Johnson (E)
W. J. Jones
J. A. Jorlett
P. L. Koehler
J. E. K. Krylow
H. L. Michael
R. W. Middleton
E. A. Miller
Frank T. Miller
H. G. Morgan (E)
T. C. Nordquist
R. E. Nottingham
G. P. Palmer (E)
R. J. Pierce
Palmer H. Slack
N. E. Smith
H. E. Snyder
D. A. Steel
B. M. Stephens
T. B. Thompson
R. R. Thurston
J. M. Trissal
T. M. Vanderstempel
V. R. Walling (E)
J. T. Ward
J. L. Way
Raymond Westcott

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report (see reports on Assignments 4 and 5)
2. Merits and economics of metal grating type crossings.
   Progress report, presented as information ..... page 326
3. Merits of various types of highway–railway grade crossing protection, collaborating with Signal Section, AAR.
   Progress in study, but no report.
4. Outline to guide highway departments and others in making applications for easements, etc.
   Final report, presented for adoption and inclusion in the Manual ..... page 327
5. Standard stop sign for use by crossing watchmen, collaborating with the Grade Crossing Protection Unit of Train Operation, Controls and Signals, AAR.
   Final report, presented for adoption and inclusion in the Manual ..... page 329
6. Problems related to location and construction of limited access highways in vicinity of or crossing railways.
   Progress report, offered as information ..... page 331
7. Sight distance at highway–railway grade crossings.
   Oral report to be made at annual meeting.
8. Recommended protection at highway–railway grade crossings where one-way traffic on the highway crosses one or more tracks on the railway.
   Brief progress statement, presented as information ..... page 331

10. The effect of highway improvement projects on railway properties, collaborating with the AAR Committee on Grade Crossing Elimination. Progress report, presented as information ..... page 333

THE COMMITTEE ON HIGHWAYS,
W. C. PINSCHMIDT, *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 2

Merits and Economics of Metal Grating Type Crossings

R. E. Nottingham (chairman, subcommittee), H. D. Blake, A. C. Cayou, R. W. Harrison, W. H. Huffman, R. W. Mauer, E. A. Miller, T. C. Nordquist, R. J. Pierce, W. C. Pinschmidt, B. M. Stephens, V. R. Walling, Raymond Westcott.

Your committee is studying three different designs of open-grating type crossings now in use. The first of these designs includes 33 crossings installed from 1945 through 1948. The steel panels in this first group are of lighter construction than those used in the other two groups under observation. The bearing bars are 2¼ in by $\frac{3}{16}$ in, compared with bars 2¼ in by ¼ in, and the frame is not as rugged.

The design of this first group of crossings calls for standard flangeway guard planks and timber filler blocks to be installed adjacent to both sides of each rail. Timber shims running parallel with the rails are used to support the 20⅞-in by 6 ft 0⅞-in steel panels and to bring the top of the panel up to the plane of the roadway surface.

Corrosion of the metal members, in spite of coating materials tried, is the limiting factor in the life of these crossings. Brine drippings from refrigerator cars, together with salt tracked on the crossings in wintertime from adjoining roadways, sets up rapid corrosion which weakens the metal members, causing welds to break and requiring replacement. One crossing of this first group, installed in 1948, was so badly deteriorated by rust that it was replaced with bituminous material in 1951. Four sections in other crossings of this group have been replaced due to damage from dragging equipment. The traffic lanes on the crossings of this group, recently observed, were found to be sealed full of dirt dropped by rail and highway traffic over the crossing. Several more of these crossings will be replaced soon with other type paving since the use of this design has been discontinued on the railroad involved.

The second design includes two crossings installed in 1949. These are reported to be in good condition at this time. The bearing bars in the panels are of 2¼-in by ¼-in steel bars. The supporting frame is made of Z bars and channels resting directly on the ties or on a shelf in concrete headwalls installed parallel to the track. The deck and supports are designed for H–20 loading. This design extends the grating 8 ft 9¾ in from center line of each track on the outside to take care of drainage at the ends of the ties. By removing the framework and decking, any type ballast cleaner can be used through a crossing of this design. The other two designs investigated by the committee only cover the length of the 9-ft ties, with no retaining wall adjacent to the highway pavement. Timber filler guards are installed on both sides of each rail for signal circuit protection.

The manufacturer recently advised that the cost of the steel grating material and metal underframe was approximately $5.50 per sq ft. This would make the cost $84 per track foot for the metal material alone. The complete crossing, including concrete headwalls, filler timbers and labor of installing, is estimated to cost close to $100 per track foot in place. We have been advised that no repairs have been necessary so far on these

crossings, and that it is rarely necessary to remove snow even up to a 12-in snowfall. The same railroad will install two more of these crossings this year in a northern climate where there is extremely heavy highway traffic.

Three crossings, using a third design, are under observation, one installed in August 1949, costing $53.42 per track foot in place, another in December 1952, costing $53.39 per track foot in place, and a third (120 ft in length), installed on a curved industry track in November 1953, costing $78.33 per track foot in place. Several additional installations are under consideration.

The deck of this third design is strongly constructed, using bearing bars 2¼ in by ¼ in. These are made up in center panels 3 ft 2 in by 4 ft 3 in, clearing the gage of each rail with a flangeway of 2¾ in. The outside panels are 3 ft 2 in by 1 ft 10 in, clearing the outside of the ball of the rail 1 in and extending to the ends of the 9-ft ties. The panels are mounted on creosoted gum shims, which are 6 in wide by 5 in thick when used with 132-lb rail. The ends of these shims are rabbeted out to clear the tie plate and spikes. A filler block is inserted in the flangeway space between the ends of the shims and the inside web of the rails. Steel plates 2 ft wide, bent and cut to fit, are installed at the receiving end of the last sections in the crossing to deflect dragging equipment up onto the deck. Marks on one of the decks indicate that dragging equipment had passed without damaging the panels.

Low maintenance cost, ease of removal and replacement, freedom from churning track and frost heaving due to aeration of ballast, and a rugged wearing surface, are some of the advantages which should be considered in comparing the higher initial cost of open-grating type crossings with other types of paving costing less for initial installation.

The second and third designs are giving excellent service and merit continued observation over a longer period of time.

This report is offered as information. Your committee desires to continue this assignment for further study and recommends the subject be continued. However, the commitee has recommended that the assignment be reworded as follows: "Merits and economics of prefabricated types of highway–railway grade crossings".

Report on Assignment 4

Outline to Guide Highway Departments and Others in Making Applications for Easements, etc.

E. R. Englert (chairman, subcommittee), H. D. Blake, C. O. Bryant, C. M. Carnahan, R. B. Carrington, Jr., J. R. Derieux, Jr., W. R. Dunn, Jr., P. W. Elmore, Maro Johnson, P. L. Koehler, R. W. Middleton, G. P. Palmer, W. C. Pinschmidt, D. A. Steel, J. L. Way.

Last year your committee developed an "outline" for the guidance of those making application for roadway easements on railway property. The outline was included in the report of the committee and was published as information in the Proceedings, Vol. 56, 1955, pages 378 and 379. When the report was presented, the committee asked for comments and criticisms from the membership regarding it and stated that the committee planned to present the outline for adoption and publication in the Manual in 1956.

During the past year the committee has revised the outline, making minor but important changes in it as the result of correspondence with consulting and highway engineers. The revised outline is now submitted with the recommendation that it be adopted and published in the Manual.

EASEMENT APPLICATIONS

(Highways–Streets–Roadways)

A. PURPOSE

This outline is for the guidance of highway personnel and others in making application for highway, street or roadway easements on railway property. Before an easement is granted, consideration must be given by several departments of the railway. By following this guide, field and office work, by both the applicant and railway, can be held to the minimum and the granting of easements greatly expedited.

B. PROCEDURE

1. Plans

The applicant shall furnish the following drawings:

a. Plan view or situation map showing:

1. Railway property lines and improvements, such as tracks, buildings, and pole lines that are likely to be involved. Railways have maps of all their property and generally will make them available to responsible organizations and individuals.

2. Boundaries of the desired easement, with both ends tied in with bearings to the center line of a main track. The tie-in points are to be located by chaining along the center line of the main track to the nearest permanent railway structure. The easement shall also be located in relation to local land survey ties where practicable.

3. Distance along the center line of main track from tie-in points to the nearest railway mile post.

4. Proposed highway, street or roadway, together with secondary structures to be installed on the easement, incidental to the highway, street or roadway.

5. Existing and proposed drainage and structures.

6. Edge of slopes.

7. Location of any construction or temporary easement.

(b) Profiles of center line of proposed highway, street or roadway, showing original ground line and proposed grade. Relative base-of-rail or top-of-rail elevation of the main track at tie-in points of the easement shall be shown.

c. Details of present and proposed drainage shall be furnished when run-off characteristics or storage are affected.

d. Cross sections of present ground line, showing proposed roadbed. The sections shall be carried to the center line of a main track when the proposed roadbed is adjacent to the track roadbed. Where a crossing of railway tracks is involved, full details as to grade of road, tracks, pavement section and crown, superelevation, construction details, and procedures shall be furnished on a large-scale detail drawing.

e. A plat showing the easement shall be furnished on 8 by 10-in or 8½ by 13-in (where practicable) vellum or other material suitable for making reproductions.

2. Submission

a. The plans shall be submitted to the chief engineer of the railway, together with a formal letter signed by the applicant or a person duly authorized to negotiate such easement. The letter shall request the easement as well as explain the need for the easement.

b. The letter of submission shall include the name of the engineer in charge of the work to be contacted for a review of the proposal on the ground.

c. A copy of the application (letter and plans) shall be sent to the railway superintendent in charge of the territory where the easement is desired. If the railway superintendent is not known, the application shall be sent in duplicate to the chief engineer.

C. GENERAL

The location of highways, streets or other roadways must be made in accordance with Arts. 1, 2, and 3 of Location of Highways Parallel With Railways, Miscellaneous Part, this Chapter, where practicable. When the location cannot be made in accordance with Arts. 1, 2, and 3, then Art. 4 of the same document shall govern.

Report on Assignment 5

Standard Stop Sign for Use by Crossing Watchmen

Collaborating with the Grade Crossing Protection Unit of Train Operation, Controls and Signals, AAR

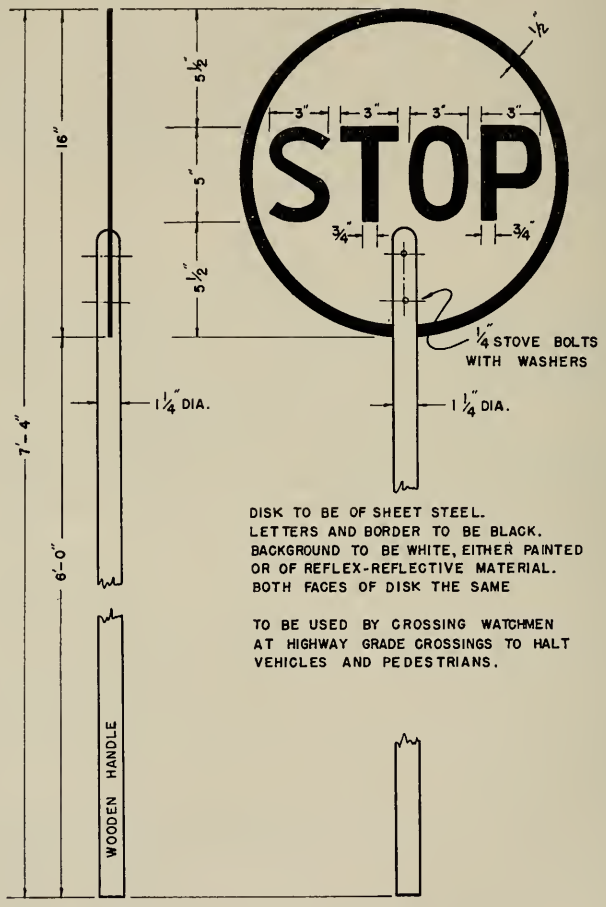
T. M. Vanderstempel (chairman, subcommittee), H. D. Blake, W. R. Dunn, Jr., Marvin Gates, R. W. Harrison, W. H. Huffman, P. L. Koehler, R. W. Middleton, W. C. Pinschmidt, D. A. Steel, B. M. Stephens, V. R. Walling, J. L. Way.

The AREA does not have a recommended standard stop sign for use by crossing watchmen, although one is contained in Bulletin 4 of the Grade Crossing Protection Unit, Train Operation, Control and Signals, Association of American Railroads.

Your committee has given serious consideration to the design of such a sign, both as to size and shape. Tests were made of larger circular disks and octagonal shape signs of several sizes, along with the present 16-in sign of TOC&S, including signs with ordinary painted surfaces of white, yellow and red, as well as surfaces coated with reflex-reflective material. The size, shape, color and design of the sign recommended by your committee are the same as those of the TOC&S sign.

Although the use of the stop sign is decreasing each year, largely as a result of an increase in the number of grade crossings being equipped with and protected by automatic devices instead of by crossing watchmen, there is still need for such a sign. (According to ICC statistics of railways in the United States, there were 2827 crossings protected by watchmen on January 1, 1954. This compared with 4375 such crossings on January 1, 1948.)

Your committee recommends for adoption and inclusion in the Manual the sign shown in the accompanying drawing, to be inserted as Fig. 9 on page 9–2–10, with appropriate additions to be made to the tabulation on page 9–2–1 to cover this sign.



STOP SIGN FOR CROSSING WATCHMAN

Fig. 9.

Report on Assignment 6

Problems Related to Location and Construction of Limited Access Highways in Vicinity of or Crossing Railways

S. B. Gill (chairman, subcommittee), H. D. Blake, Raymond Dejaiffe, J. R. Derieux, Jr., A. D. Duffie, J. S. Felton, H. F. Gilzow, J. T. Hoelzer, W. J. Jones, H. L. Michael, Frank T. Miller, G. P. Palmer, W. C. Pinschmidt, Palmer H. Slack, H. E. Snyder, R. R. Thurston.

This report is offered as information, with the recommendation that the subject be continued.

A limited access highway may be defined generally as a highway especially designed for through traffic and to which abutting property owners have no right of access. Access may be had only at specified locations.

In some instances these access restrictions are modified to the extent that such access may be had by abutting owners as is reserved pursuant to the map and description of lands to be appropriated. Service highways, to provide access to and from areas adjacent to a limited access highway, may also be provided if they are deemed necessary in the public interest.

Any abutting property owner has an inherent right of entry to and from a public highway. In establishing limited access highways, this inherent right of abutting owners must be acquired from the owner by purchase, gift, agreement or condemnation. A railway, as a property owner, may therefore assert its right of access to a limited access highway that abuts its property and seek a form of compensation for such loss of rights.

Problems related to the location of limited access highways in the vicinity of railways are as follows:

1. Loss of access if the limited access highway replaces an existing public way.
2. Inability of railway to serve lands lying beyond the highway that may be suitable for industrial development.
3. Access to intervening lands by an industry desiring to locate between the railway and a limited access highway.

Other problems relating to the location and construction of limited access highways are common to the location and construction of any highway. These problems are outlined in the Manual under Location of Highways Parallel with Railways, Miscellaneous Part, Chapter 9.

Report on Assignment 8

Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railway

D. W. Hughes (chairman, subcommittee), M. H. Corbyn, Raymond Dejaiffe, S. B. Gill, C. I. Hartsell, Wm. J. Hedley, W. H. Huffman, W. J. Jones, J. E. K. Krylow, R. W. Mauer, W. C. Pinschmidt, Palmer H. Slack, T. B. Thompson, T. M. Vanderstempel.

Your committee submits the following initial report of progress in the gathering of information pertaining to physical adjustments to be made in highway–railway grade crossing protection practices as known in the past.

The growing popularity of one-way vehicular traffic routes, both in metropolitan and outlying districts, together with such routes in areas where the vehicular traffic volume has so swollen as to make one-way traffic a necessity, is creating a rapidly spreading condition over which responsible authorities are much concerned. As the result of discussions, both legal and of a practical engineering nature, questions have arisen and fears have been expressed concerning this development.

The following brief chronology serves to point up the importance of this assignment.

At the outset, the rate of accidents and the increased volume of vehicular traffic forced the roadway authorities to adopt stringent measures and to seek immediate solution to a traffic problem forced upon them by public clamor, police safety surveys and, in some instances, by deferred engineering considerations.

The results have been explosive in nature in certain localities. Cities have created one-way streets in wholesale fashion. State highway departments have built separated traffic portions with median strips varying from 36 in to 30 ft or more in width. Counties have been forced to consider the strong prospect of using one County road solely for one-way traffic, and shifting reverse movement traffic to the adjacent parallel road on the nearest section line, whereby each road contributes traffic to the other.

These plans permit those not having funds available for extensive road improvement or increased multiple-lane projects to meet the traffic requirements, at least for the present.

All of this focuses attention on the highway–railway crossing at grade where one-way highway traffic is involved. It also introduces a phrase to be associated with instances hereafter—The vehicular traffic approach side. This refers not only to the side of the track on which the mast of the grade crossing protection device shall stand, but also the direction that signs or flashing-light signal lamps shall face.

Important issues or problems created over such eventuality as one-way road crossings with railway tracks are those dealing with such questions as, "What of sudden reversal, or emergency re-establishment of two-way traffic?"; "What of a planned two-way traffic operation for a period during a road construction project, creating a detour?"

These and other questions have been discussd in conferences between roadway authorities on all levels, police agencies having to do with traffic control, and representatives of railroads in the localities involved.

Out of such talks have come assurances that the roadway plans are stable. Emergencies must be anticipated, with attendant policing of the one-way rail crossing until relieved. Also, that planned reversals or re-establishment of two-way operations must be the subject of prior arrangement, permitting adequate adjustment and protection as required. Further, that the raliroads can arrange for temporary signaling if needed.

This matter resolves itself into the question of appropriate treatment that should be extended as a form of good practice.

It is expected that recommendations will be developed through further study by the committee. Suggestions and comments from Association members are requested and will be most welcome. The report is submitted as information, with the recommendation that the subject be continued.

Report on Assignment 10

The Effect of Highway Improvement Projects on Railway Properties

Collaborating with the AAR Committee on Grade Crossing Elimination

J. T. Hoelzer (chairman, subcommittee), H. D. Blake, Bernard Blum, C. M. Carnahan, R. B. Carrington, Jr., A. C. Cayou, A. D. Duffie, S. B. Gill, J. A. Jorlett, H. L. Michael, T. C. Nordquist, W. C. Pinschmidt, N. E. Smith, J. M. Trissal, J. T. Ward.

Your committee presents the following material as information, with the view of recommending its adoption and inclusion in the Manual next year.

THE EFFECT OF HIGHWAY IMPROVEMENT PROJECTS ON RAILWAY PROPERTIES

Railways may be involved physically in highway improvement projects by the construction of overhead or undergrade structures, the elimination of highway–railway grade crossings, the establishment of additional grade crossings, and the relocation of existing grade crossings. They may also be involved as the result of necessary changes in the form of grade crossing protection, and the removal, relocation or alteration of tracks and railway structures. Such projects may affect industrial development and railway expansions, and may result in diversion of railway traffic.

In a highway–railway grade separation project, consideration should be given to costs through capital expenditures, maintenance and taxation; how train operation may be affected; and whether industrial or railway terminal expansion would be restricted. A grade separation project should result in a reduction of accident potential and a reduction of expense for maintaining the crossing and crossing protection.

If a highway improvement project crossing a railway does not include the separation of grades, consideration should be given to the possible increased costs created by a wider and improved type of crossing; improvement of drainage facilities at and in the vicinity of the crossing; augmentation of crossing protection; and the purchase of additional property in the quadrants of the crossing for improvement of sight distances by grading and restricting the use of triangular areas. Consideration should also be given to the increase in grade crossing accident potential; how train operation might be affected; and the possibility of consolidating several public or private crossings into a single improved grade crossing.

For a highway improvement paralleling a railway, consideration should be given to how the highway grade and more rapid runoff of surface water will affect the railway; how highway grading and construction work may affect railway property; whether there is the probability of highway vehicles accidentally getting onto tracks or railway property; possible restriction to industrial developmnt and railway expansion; increased cost to construct and protect tracks over improved highways; and increase in switching costs and accident potential for tracks that may cross such highways.

Generally, highway improvement projects enhance the competitive position of highway transportation agencies.

Report of Committee 13—Water, Oil and Sanitation Services

H. L. McMULLIN,
Chairman,

H. M. SCHUDLICH,
Vice Chairman,
E. C. HARRIS, *Secretary,*
W. F. ARKSEY

G. A. AUSBAND
R. A. BARDWELL
R. C. BARDWELL (E)
J. M. BATES
M. R. BOST
I. C. BROWN
GEORGE CLARK
R. E. COUHGLAN
B. W. DEGEER (E)
D. E. DRAKE
J. J. DWYER
C. E. FISHER
C. J. FRESEMAN
R. S. GLYNN
H. E. GRAHAM
E. M. GRIME (E)
F. E. GUNNING
S. H. HAILEY
M. A. HANSON
T. L. HENDRIX, JR.
T. W. HISLOP, JR.
H. M. HOFFMEISTER
A. W. JOHNSON
C. O. JOHNSON
J. J. LAUDIG
G. F. METZDORF
THEODORE MORRIS
J. Y. NEAL
JOHN NORMAN
A. B. PIERCE (E)
N. B. ROBERTS
J. P. RODGER
E. R. SCHLAF
H. E. SILCOX (E)
H. M. SMITH
R. M. STIMMEL
L. E. TALBOT
D. C. TEAL
T. A. TENNYSON, JR.
J. E. TIEDT
A. G. TOMPKINS
J. H. UPHAM
J. W. USSHER
H. W. VAN HOVENBERG
C. B. VOITELLE
C. L. WATERBURY
J. E. WIGGINS, JR.
E. L. E. ZAHM

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Types of corrosion in railway water and fuel service, collaborating with Mechanical Division, AAR.
   No report.

3. Federal and state regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR.
   Progress report, presented as information ..... page 336

4. Cathodic protection of pipe lines and steel storage tanks, collaborating with the Electrical Section, AAR.
   Brief statement of progress, presented as information ..... page 337

5. New developments in water conditioning for diesel locomotive cooling systems, collaborating with Mechanical Division, AAR.
   Progress report, presented as information ..... page 337

6. Railway waste disposal, collaborating with Joint Committee on Railway Sanitation, AAR.
   Progress report, presented as information ..... page 338

7. Treatment of water for cooling purposes.

   Progress report, presented as information ..... page 339

8. Diesel oil and water servicing facilities, collaborating with Mechanical Division, AAR.

   Final report, submitting material for adoption and printing in the Manual . page 342

9. Disinfectants, deodorants, fumigants and cleaning materials, collaborating with Joint Committee on Railway Sanitation, AAR.

   Progress in study, but no report.

10. Detection and disposal of radioactive materials in air, oil and water filters on diesel locomotives and other equipment, collaborating with Joint Committee on Railway Sanitation, AAR.

    Brief statement of progress, presented as information ..... page 344

11. Design of plants and treatment methods for small drinking water supplies where approved public supplies are not available, collaborating with Joint Committee on Railway Sanitation, AAR.

    No report.

12. Sterilization of new and repaired water wells, pipe lines and other equipment used in handling drinking water, collaborating with Joint Committee on Railway Sanitation, AAR.

    Final report, presenting material for adoption and printing in the Manual . page 344

THE COMMITTEE ON WATER, OIL AND SANITATION SERVICES,
H. L. McMULLIN, *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 3

Federal and State Regulations Pertaining to Railway Sanitation

Collaborating with Joint Committee on Railway Sanitation, AAR

H. W. Van Hovenberg (chairman, subcommittee), J. M. Bates, M. R. Bost, I. C. Brown, C. J. Freseman, E. M. Grime, F. E. Gunning, S. H. Hailey, A. W. Johnson, Theodore Morris, D. C. Teal, J. E. Wiggins, Jr.

This is a progress report, presented as information.

Your committee summarizes for this year the activities of the Joint Committee on Railway Sanitation, AAR, composed of representatives of the Engineering and Mechanical Divisions, the Medical and Surgical Section, Operating–Transportation Division, the U. S. Public Health Service, and the Department of National Health and Welfare of Canada.

The Joint Committee, through its special subcommittee, has continued to supervise the activities of AAR Sanitation Research and Development, which group is located at the Association's Research Center in Chicago, and has made recommendations for its maintenance and budget in 1956.

Through the Sanitation Research and Development Unit, studies have been progressed on various phases of railroad sanitation such as waste disposal, potable water and water

hydrants, industrial cleaning chemicals, food handling for dining department personnel, laboratory facilities and their utilization, etc. Contact has been maintained and expanded with railroad representatives over the country on the general subject of sanitation.

The Joint Committee has also continued to serve as liaison with the U. S. Public Health Service on aspects of sanitation related to railroad operations.

Your representatives on the Joint Committee are T. L. Hendrix, Jr., J. E. Wiggins, Jr., and H. W. Van Hovenberg, the last named serving also as the engineering representative on the special subcommittee.

Report on Assignment 4

Cathodic Protection of Pipe Lines and Steel Storage Tanks

Collaborating with Electrical Section, AAR

W. F. Arksey (chairman, subcommittee), R. A. Bardwell, C. E. Fisher, H. E. Graham, C. O. Johnson, G. F. Metzdorf, Theodore Morris, J. Y. Neal, John Norman, D. C. Teal, J. H. Upham, C. L. Waterbury.

Your committee presents the following report of progress toward a final report on cathodic protection of pipe lines and steel storage tanks.

During the year a questionnaire was circulated among all the members of Committee 13 in response to which a good percentage of replies were received with generous comments. It was developed that the majority of the committee favors a final report that will outline procedures to be followed in making surveys for the design of cathodic protection systems. Accordingly, we propose to present a schedule that will allow a railroad to handle the majority of cathodic protection systems required on their lines. Large systems should be designed by competent corrosion engineers because of the possibility of complications arising from unusual conditions.

Up to the present time most railroads have not applied cathodic protection to their pipe lines because of the relatively high cost of survey to the value of line. Therefore, some knowledge of procedure would allow most engineers to protect lines, at least to the extent of arbitrarily placing anodes that would over protect a small installation.

This report is presented as information.

Report on Assignment 5

New Developments in Water Conditioning for Diesel Cooling Systems

Collaborating with Mechanical Division, AAR

M. A. Hanson (chairman, subcommittee), I. C. Brown, D. E. Drake, J. J. Dwyer, E. C. Harris, R. M. Stimmel, T. A. Tennyson, Jr., J. E. Tiedt, A. G. Tompkins, J. W. Ussher, E. L. E. Zahm.

During the past year laboratory tests have been conducted using sodium molybdate as a corrosion inhibitor. The tests were run at a pH of 8.5–9.5, using both soda ash and trisodium phosphate to raise the pH of the test solutions to the desired values.

The concentration of the sodium molybdate was varied from 100 ppm up to 2000 ppm during different tests. These tests indicated alkaline sodium molybdate is an effective inhibitor against corrosion for all of the metals commonly found in a diesel cooling system, except cast iron.

One field test of short duration was conducted. This test was discontinued before conclusive results were accumulated, and because of the unfavorable results on cast iron during laboratory tests, no further testing is now contemplated.

A number of railroads tested two different soluble oils as corrosion inhibitors. These oils seemingly gave a considerable degree of corrosion protection for the relatively short duration of the tests. Whether the corrosion protection would be satisfactory over an extended period is not known. The tests were discontinued on account of other cooling system difficulties. The oil emulsions were not stable, resulting in oil separation. In some instances the oil coatings on the radiators reduced the rate of heat dissipation to too great a degree. Radiator hose troubles were widespread. One railroad experienced severe sludging in the cooling system.

Although the tests reported above do not give encouragement that either of the compounds tested could be substituted satisfactorily for the presently used inhibitors, it is believed desirable to report the results of the tests. This is being done simply as an addition to the sum total of the knowledge on the subject.

At this time no new types of inhibitors are being tested and no tests are contemplated.

This is a progress report, submitted as information.

Report on Assignment 6

Railway Waste Disposal

Collaborating with Joint Committee on Railway Sanitation, AAR

T. A. Tennyson, Jr. (chairman, subcommittee), W. F. Arksey, J. M. Bates, M. R. Bost, F. E. Gunning, S. H. Hailey, T. L. Hendrix, Jr., J. J. Laudig, J. Y. Neal, N. B. Roberts, R. M. Stimmel, J. E. Wiggins, Jr.

In line with past practice your committee has continued to keep informed with respect to state and federal regulations pertaining to the disposal of liquid industrial wastes as reported in the various trade and technical magazines, and no basic changes have been indicated.

This year your committee has also solicited discussion of the experiences of the railroad members on the committee in the operation of facilities for separating oil from waste water when emulsions are present. Several replies indicate that when emulsions are present the simple mechanical means of oil separation by gravity traps, as described in AREA Proceedings, Vol. 50, 1949, page 190, must be augmented by chemical methods in which an insoluble solid is formed, or by means of breaking the emulsion so that the oil will rise to the surface of the water where it can be skimmed off. Where the amount of oil is small, filtration methods, such as the use of bales of hay in the channel leading to the receiving waters, may be all that is required. Ordinarily it is desirable to remove any free or floating oil before proceeding to any of the supplementary chemical methods for dealing with the emulsified oil.

Chemical methods in which an insoluble solid is formed involve the use of coagulants, widely known in water treatment, such as alum, sodium aluminate, ferrous and ferric salts and sodium silicate. Under the proper conditions of pH these materials form a flocculent, insoluble agglomeration, which will settle out of the water and carry the oil with it. This insoluble material and oil can then be removed in sedimentation basin or retention tanks.

If the emulsions have been stabilized by materials which can be neutralized by acids, they can be broken by the addition of suitable quantities of acid and the oil will rise to the surface where it can be skimmed off. Since most state regulations require that the waste water be above a minimum pH value before it can be put into streams, the use of this method will require laboratory control for pH adjustment of the waste water after the oil has been removed.

There is no universal method of chemical treatment of waste water for breaking emulsions and the removal of oil, so the design and procedure must be selective. Laboratory control is essential to the satisfactory operation of the chemical methods of oil separation.

Several methods used by the petroleum industry for breaking emulsions, so oil can be separated from waste water by mechanical means, do not appear applicable to railroads because of requirements for heat, steam, or high-voltage electricity and outlay for equipment. There are, however, a number of proprietary emulsion-breaking compositions used by the petroleum industry which give promise for railroad use. Just as with the methods of chemical treatment, there is no "cook book" method for the use of these materials and their selection depends on whether the emulsions are of the oil-in-water or water-in-oil type, among other things. The manufacturers of such emulsion-breaking compositions will analyze waste water samples and prescribe methods of treatment, or they will furnish samples of their products for experimental purposes.

Replies to your committee's questionnaire reveal that four railroads have either proposed or are actually operating waste disposal facilities which handle emulsified oil, using chemical methods of coagulation or emulsion breaking with acids. No replies indicated that filtration methods or any of the proprietary emulsion-breaking compositions are in use on railroads at the present time. If members of the AREA, other than Committee 13, know of any such methods in current use, it will be appreciated if they will advise the committee.

This report is presented as information.

Report on Assignment 7

Treatment of Water For Cooling Purposes

L. E. Talbot (chairman, subcommittee), I. C. Brown, D. E. Drake, J. J. Dwyer, C. E. Fisher, M. A. Hanson, E. R. Schlaf, T. A. Tennyson, Jr., A. G. Tompkins, J. W. Ussher, E. L. E. Zahm.

The increased use of air conditioning, both in railroad rolling equipment and office buildings, and the increased use of internal combustion engines on railroads during the past few years, have introduced new problems in water treatment. Last year your committee presented information (Proceedings, Vol. 56, 1955, pages 347 to 355, incl.) on the various types of cooling systems involved, together with the types of scale and corrosion formations found in these systems. The report also outlined some of the current methods used to prevent these formations. This current report of the committee is the final part of its report, presented as information, and outlines some of the problems encountered due to slime and algae present in the cooling system, and due to the gradual deterioration of the wood of the cooling tower. The report also discusses the current methods for the solution of the above problems.

A. SLIME AND ALGAE FORMATIONS

The three main groups of organisms which may give trouble in recirculating cooling water systems are as follows:

1. Algae Group—This group may be divided into three types: the blue green, the green, and the diatoms. The blue green and green algae flourish only in that portion of the system exposed to light and air. These two types cause trouble in that they restrict the flow of water and/or air in the cooling tower. The diatoms are composed largely of silica and, on chemical analysis, this deposit might look like a mineral deposit. The diatoms are found in natural water supplies and cause trouble by forming deposits in piping, filters, or similar equipment.

2. Bacteria Group—Contrary to common belief, certain types of bacteria, and not algae, are responsible for a great deal of slime found in piping and exchangers of a cooling system. This group may also be divided into three types; the slime forming, the corrosive or sulfate reducing, and the iron-depositing bacteria. Recognition of the fact that all bacteria are not slime forming is a very important step in interpreting analytical results. The relative number of these types of bacteria present indicates that degree of trouble caused by them. The corrosive type of bacteria reduces the sulfate in the water to sulfide, which is extremely corrosive in a water system. The iron-depositing type of bacteria are those which take in solution iron and give off insoluble iron in the form of a slimy sheath around their cells. The resulting deposit is actually composed of iron oxide skeletons of dead bacteria. Usually, the iron-depositing bacteria are found in well water supplies. They are troublesome in that they cause deposits of slimy iron oxides in the piping systems of the cooling installations.

3. Fungi Group—There are actually two types of fungi which cause trouble in cooling water systems. These are the yeast and molds. Both molds and yeast may result from air borne contamination of the cooling system.

B. METHODS OF TREATMENT FOR SLIME AND ALGAE PREVENTION

Before any type of control is recommended for slime and algae prevention, an analysis of the cooling water, and the raw water, and the organisms in the slime should be made. For example, if no fungi or algae is found by analysis of the slime, than probably all the trouble is due to bacteria and a bactericide is required. If the fungi group is the offender, than a fungicide should be used. The analysis of the raw water and cooling water is necessary to determine those organisms which might not be present in the slime sample.

Some of the methods use for the prevention of slime and algae in cooling systems are as follows:

1. Chlorination—Intermittent chlorination is commonly used for the control of slime in once-through systems; however, in recirculating systems the disadvantage of using chlorine is that the excess chlorine is removed by aeration when the water is passed over the cooling tower. Usually the chlorine is shot-fed, and a residual of several parts per million (depending on the amount of slime present in the system) is maintained for 30 min periods at 24-hr intervals.

2. Bromine—The use of bromine for the control of slime and algae gives satisfactory results. However, due to the high cost and the hazards involved in its use, it is neither practical nor economical. The combination of continuous chlorination with shock bromine treatment gives satisfactory control of slime and algae and a definite cost reduction compared with either of the two used separately.

3. Copper Sulfate—This chemical has been used to prevent algae growth and is effective against certain strains of algae particularly resistant to chlorine. It is not lost through aeration in the tower, but its use is limited by the fact that copper precipitates at pH values of 8.5 and over. Copper sulfate requirements for treatments of various organisms vary from 0.10 to 0.50 parts per million, depending on the type present.

4. Copper Citrate—This compound is sometimes used instead of copper sulfate. Its stability in solution and high solubility in alkaline waters makes it more effective than copper sulfate. Good control of slime and algae has been maintained using from 10 to 30 parts per million of copper citrate added at intervals of 2 to 7 days, depending upon the growth rate of the algae.

5. Sodium Pentachlorophenate—This compound has proven effective in many instances for the control of slime and algae in recirculating systems. This material is soluble and stable in alkaline waters and does not react with most organic and inorganic chemicals which might be present in the system. The blow down discharge should be carefully regulated when using this compound because of its toxicity to fish and animals. Slug feeding of the pentachlorophenate has proven more effective than continuous feeding. Good control is established by adding 200 parts per million to the circulating water; when the concentration is depleted, another slug is adedd. Considerable success has been achieved by combining the phenolic compound with the copper salts. Satisfactory results can be obtained using 60 to 100 parts per million of the combination instead of the 200 parts per million of the phenolic compound alone.

6. Quaternary Ammonium Compounds—The quaternary ammonium compounds are of rather recent development. These materials show effective toxicity towards slime and algae growth when used in relatively high concentrations. It has been found that certain compounds have been lost in cooling tower systems due to volatilization. The presence of high salt concentrations in the water also greatly reduce the effect of these materials. Since quaternary ammonium compounds possess effective surface active properties, some work has ben done with these materials in combination with other slime control agents. Alkyl dimethyl benyl ammonium chloride is one of the many types of quaternary ammonium compounds presently available.

C. CHEMICAL ATTACK AND ITS CONTROL IN COOLING TOWERS

Chemical deterioration of cooling tower wood, known as delignification, involves the removal of the lignin binder from the cellulose fibers. This results in a fibrous cellular structure of low strength. Tests have proven that neutral salts have little or no effect on wood; however, the principal constituents of woods, cellulose and lignin, are attacked by acid and alkaline waters, respectively.

In the case of delignification, sodium carbonate is the known offender. Sodium carbonate may be present in the cooling tower makeup water. Usually the presence of sodium carbonate is due to lime or lime-soda-ash softening of the make water since sodium carbonate is not generally found in untreated supplies. Sodium carbonate may also develop where sodium zeolite softening of the make water is practiced.

It is possible to utilize the measurement of pH in the water as an indication of the amount of sodium carbonate present. This is because a high pH is usually due to the concentration of sodium carbonate, since free hydroxide is seldom encountered. In order to prevent delignification of the cooling tower due to sodium carbonate it is necessary to maintain the pH of the water between 7.0 and 7.5. If the acid is used to control this pH, it should be noted that there is some wood destruction which can not be classified as delignification, which becomes appreciable as the pH drops to 5.0 or lower.

Distribution of the water over the tower is another important factor affecting delignification. The rate is greater in those areas where salt incrustation is allowed to occur. This takes place in non-operative sections of the cooling tower which are so located that they undergo alternate wetting and drying, resulting in salt formations. Periodically washing those sections which have these salt formations appears to be the most economical means of controlling this trouble.

D. BIOLOGICAL ATTACK AND ITS CONTROL IN COOLING TOWERS

Biological destruction of cooling towers is caused by micro organisms that utilize the wood for food. Different species of fungi attack different constituents of the wood. Most wood destroyers attack cellulose, leaving a dark residue which is known as "brown-rot". This type of decay has been found only at points where the wood is in contact with iron fastenings or where water dripping from iron strikes it. It is always found in sections of a tower which are moist, but not flooded by the recirculating water.

Another type, but rare, are the fungi that destroy the lignin. These sometimes produce a "white-rot" or reduce the wood to a light colored mass which is sometimes stringy. The white-rot found in cooling towers follows a different pattern than the brown-rot. Rather than being confined to a relatively small piece of lumber, it will spread through the entire board as well as on to adjacent lumber. Too, the white-rot can be found in practically all parts of the cooling tower.

Biological attack on cooling tower wood is not as thoroughly understood as delignification. As a preventative measure, it would seem that the use of algicides that will be absorbed by the wood would prove more effective than chlorine in the control of this problem. Copper and chlorophenate materials, or combinations of this type, as discussed under Sec. B of this report, would be effective in controlling the biological attack. Although wood preservatives have been employed for many years to protect against decay, little data exist on its effect on cooling towers.

Report on Assignment 8

Diesel Oil and Water Servicing Facilities

Collaborating with Mechanical Division, AAR

D. C. Teal (chairman, subcommittee), W. F. Arksey, G. A. Ausband, C. E. Fisher, H. E. Graham, F. E. Gunning, S. H. Hailey, H. M. Hoffmeister, John Norman, N. B. Roberts, J. H. Upham, C. B. Voitelle, C. L. Waterbury, J. E. Wiggins, E. L. E. Zahm.

The railroads have been more or less dieselized for a number of years and considerable study has been given to the design, construction and operation of diesel fueling and watering facilities. Several years ago it was felt that the research and experimental phases of these facilities had progressed to the point where recommended practices should be promulgated. As a result, the subject was assigned to this committee, and, following careful study, a report, embracing recommended practices, was made to the Association at its 1955 annual meeting (see Proceedings, Vol. 56, 1955, page 535–568, incl.), with the understanding that the assignment would be continued for another year in order to collaborate further with other interested organizations, and otherwise to give further consideration to the material submitted.

Your committee has accordingly carefully reviewed last year's report, and with minor revisions in it and the rearrangement of some material, now submits the material, as revised, for adoption and publication in the Manual. This recommendation has the approval of collaborating organizations.

In accordance with the Association rule that proposed Manual material should not be reprinted in reports if it appeared in a report, in substantially identical form, not more than one year before being submitted for adoption, the proposed material is not reprinted herein. However, your committee points out in the following the more important of the revisions made in last year's report, largely upon the recommendations of collaborating organizations.

The next to last sentence at bottom of page 359 has been changd to read: "At main line stations where fast fueling of multiple units is required, the pumping equipment should be designed to provide a 200 to 300 gpm rate of flow simultaneously to each diesel unit."

The material at top of page 362 appearing under E. Unloading Facilities, has been revised and rearranged to emphasize the advantages of overhead or dome unloading, especially from a fire protection viewpoint.

The second sentence under "Paving of Fueling Areas" appearing on page 364 has been replaced by one which reads: "Removal of ice and snow by hand, which can become an expensive maintenance problem, has in several cases been eliminated by the installation of radiant heating coils in the concrete."

The first two paragraphs devoted to electrical work appearing on page 364 have been changed to read:

"Electrical Installations: Should conform to governing state and local codes, or in the absence of such codes, to the latest revision of the National Electric Code. Fuel oil pump houses would be considered a hazardous location under this code and would require explosion-proof equipment. All electrical work should be made vapor proof and motors should be totally enclosed and have a sealed terminal box. The wiring should be appropriate to the degree of hazard. Circuit breakers and starters should be in dust-tight, vapor-proof cases. In this connection many railroads install switches and starters in a panel box outside the pump house."

The sentence devoted to "Portable Equipment," appearing at extreme bottom of page 364, has been changed to read:

"Portable Equipment: Hand fire extinguishers of appropriate size should be located both inside and outside pump houses and also convenient to unloading points and fueling areas. There should be at least two such extinguishers at the fueling area, so placed as to minimize the likelihood of both being surrounded by fire at the same time. Dry powder extinguishers are recommended for this service. The ones located outside should be fully protected against the weather, housed in cabinets, painted red and otherwise identified."

As indicated earlier in this report, the committee now submits the material on diesel oil and water servicing facilties, as revised, for adoption and publication in the Manual.

Report on Assignment 10

Detection and Disposal of Radioactive Materials in Air, Oil and Water Filters on Diesel Locomotives and Other Equipment

Collaborating with Joint Committee on Railway Sanitation, AAR

J. M. Bates (chairman, subcommittee), H. M. Schudlich, B. W. DeGeer, R. S. Glynn, E. M. Grime, H. M. Hoffmeister, J. J. Laudig, John Norman, L. E. Talbot, J. E. Tiedt, C. B. Voitelle.

This is a progress report, submitted as information.

During the time of the tests conducted by the Atomic Energy Commission from February to June 1955, incl., several atomic bombs were exploded on Yucca Flats in the vicinity of Las Vegas, Nev.

Concurrent with these tests, the office in charge of the off-site activities ran numerous tests in connection with the fall-out materials and radioactive association with these various atomic tests on the Union Pacific Railroad right-of-way between Las Vegas and Salt Lake City, Utah. The Atomic Energy Commission tests indicate that most of the readings were negative in nature relative to the current standards and do not exceed their standards for the 1955 atomic tests relative to radioactivity along the right-of-way—exposed railroad cars, locomotives, buildings, etc.

We were also advised by James G. Terrill, Jr., chief, Radiological Health Program, Division of Sanitary Engineering Services, of the Department of Health, Education and Welfare, that no serious exposures were observed relative to contamination of rolling equipment, oil, water and air at the time the bombs were being detonated.

On June 13, members of Subcommittee 10 were furnished a copy of the methods for determining radioactivity in water and a glossary of terms relating to nuclear physics, together with other necessary information relative to fusion material. All of this information is available in the Radiological Health Handbook compiled by the Radiological Health Training Center, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Report on Assignment 12

Sterilization of New and Repaired Water Wells, Pipe Lines and Other Equipment Used in Handling Drinking Water

Collaborating with Joint Committee on Railway Sanitation, AAR

T. L. Hendrix (chairman, subcommittee), George Clark, R. E. Coughlan, C. J. Freseman, T. W. Hislop, Jr., C. O. Johnson, J. Y. Neal, E. R. Schlaf, H. W. Van Hovenberg, C. L. Waterbury.

This report, which constitutes a consolidation of current procedures in water main and well sterilization used by member railroads, together with recommendations of various state health agencies and the American Water Works Association, is submitted with the recommendation that it be adopted and included in the Manual under Part 8—Sanitation.

STERILIZATION OF NEW AND REPAIRED WATER WELLS, PIPE LINES AND OTHER EQUIPMENT USED IN HANDLING DRINKING WATER

A. GENERAL

Various components of a drinking water system are subject to polution during construction or repair work. Harmful bacteria may be introduced into wells or spring basins by handling of the equipment or from contact with foreign substances. The interior of water pipe may become contaminated before installation or while the line is being made up in the trench.

Wells and drinking water lines should, therefore, always be sterilized following new construction or when the system has been opened for repair work. The efficiency of the sterilization should then be checked by bacteriological tests wherever possible, and, if necessary, the process repeated.

The protection afforded by disinfecting an improperly located or constructed well is only temporary. If surface contamination is entering the well, construction faults must be corrected or continuous sterilization provided if the well is to be used.

B. STERILIZING AGENT

An effective and economical method of sterilizing wells, springs, pipe lines and other appurtenances is by use of a chlorine solution which may be easily prepared from sodium hypochlorite laundry bleach, high-test calcium hypochlorite or chlorinated lime. The calcium compounds should first be made into a paste and then thinned to a one percent chlorine solution. This solution requires the following proportions:

Product	*Amount of Compound*	*Amount of Water*
Liquid laundry bleach (5 percent Cl)	1 gal	4 gal
High-test calcium hypochlorite (65–70 percent Cl)	1 lb	7.5 gal
Chlorinated lime (32–35 percent Cl)	2 lb	7.5 gal

The total amount of chlorine solution used should be calculated to provide a minimum dosage of 50 ppm chlorine.

C. STERILIZING PROCEDURE

1. Shallow Wells

a. Wash the interior walls of the casing with chlorine solution, using a stiff broom or brush to assure thorough cleaning.

b. Pump water from well until it is clear; then remove pumping equipment.

c. Place cover over the well and pour required amount of chlorine solution into the well through the manhole or pipe sleeve opening just prior to inserting the pump cylinder and drop-pipe assembly.

d. Wash exterior surface of the pump cylinder and drop-pipe with the chlorine solution as the assembly is being lowered in the well.

e. After the pump has been set, pump water from the well until a strong odor of chlorine is noted.

f. Allow chlorine solution to stand in well for not less than 12 hr; then flush well by pumping water to waste to remove all trace of chlorine.

2. Drilled and Bored Wells

a. When being tested for yield, the well should be bailed or pumped until water is clear.

b. After testing equipment has been removed, pour required amount of chlorine solution into the well slowly just prior to installing the permanent pumping equipment. Diffusion of the chemical with the well water may be facilitated by running the solution into the well through a hose or pipe line as the line is being alternately raised and lowered.

c. Wash the exterior surface of the drop-pipe assembly with the chlorine solution as it is being lowered in the well.

d. After the pump has been set, pump water from the well until a strong odor of chlorine is noted. If it is an automatic pump with pressure tank, allow tank to fill completely so that portions above normal water line will be disinfected.

e. Allow chlorine solution to stand for not less than 12 hr; then flush well by pumping water to waste to remove all trace of chlorine.

3. Drinking Water Lines*

a. Keep interior of pipes free from foreign matter. Block open ends to keep trench water out of pipes.

b. Avoid use of jute or hemp packing. Use solid molded or tubular rubber rings, asbestos rope, treated paper rope, or braided cotton.

c. Before disinfecting, flush line at velocity of at least 2.5 ft per sec.

d. Chlorinate to give a uniform dose of at least 50 ppm. Apply chlorine at one extremity of pipe section and bleed at opposite end. Take precautions to prevent dosed water from flowing into potable water supply.

e. After 12 hr flush out heavily chlorinated water before placing line in service.

* See AWWA C601—A Standard Procedure for Disinfecting Water Mains.

Report of Committee 20—Contract Forms

W. D. Kirkpatrick, *Chairman,*

E. M. Hastings, Jr., *Vice Chairman,*

C. B. Niehaus, *Secretary,*

J. P. Aaron
G. H. Beasley
K. A. Begemann
H. F. Brockett
R. G. Brohaugh
R. F. Correll
A. B. Costic
G. K. Davis
G. K. French
C. L. Gatton
J. F. Halpin
J. R. Harris
R. C. Heckel
C. J. Henry
H. W. Legro
J. S. Lillie (E)
L. W. Lindberg
D. F. Lyons
W. L. Mogle
J. W. McMillen
O. K. Morgan (E)
W. G. Nusz (E)
R. O. Nutt
G. W. Patterson
J. L. Perrier
E. E. Phipps
W. R. Swatosh
J. W. Wallenius
W. E. Webb
D. J. White
I. V. Wiley
D. H. Yazell
Clarence Young
H. L. Zouck

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1 Revision of Manual.

Progress report, including recommended revisions ..... page 348

3. Form of lease covering subsurface rights to mine under railway miscellaneous physical property.

Brief progress statement, presented as information ..... page 350

5. Insurance provisions recommended for various forms of agreements.

Progress report, presented as information ..... page 350

6. Form of agreement for turnpike or toll road crossing railway tracks and property.

Submits tentative draft of agreement, as information ..... page 355

The Committee on Contract Forms,
W. D. Kirkpatrick, *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 1

Revision of Manual

W. R. Swatosh (chairman, subcommittee), C. L. Gatton, J. R. Harris, E. M. Hastings, Jr., C. J. Henry, J. S. Lillie, D. F. Lyons, J. W. McMillen, O. K. Morgan, W. G. Nusz, G. W. Patterson.

Your committee offers the following recommendations with respect to the Manual:

Pages 20–1–13 to 20–1–22, incl.

FORM OF COST-PLUS PERCENTAGE CONSTRUCTION CONTRACT

In conformance with its assignment, the committee has reviewed the Form of Cost-Plus Percentage Construction Contract. This review disclosed that the paragraph pertaining to Independent Contractor is incorrectly positioned, and that Secs. 12 and 13 should be rewritten in order that the text of this agreement will be in harmony and on a current basis with other Manual agreements insofar as the insurance and indemnity provisions are concerned.

The committee recommends reapproval of the form with the following revisions and additions:

Page 20–1–13: In the paragraph immediately following the WITNESSETH clause, insert after the word "included" contained in the last line thereof, the words "by reference".

Eliminate the second paragraph following the WITNESSETH clause.

Page 20–1–14: Insert the following new section:

1. Independent Contractor

The Company reserves no control whatsoever over the employment, discharge, compensation of, or services rendered by the Contractor's employees, and it is the intention of the parties to this agreement that the Contractor shall be and remain an Independent Contractor, and nothing in this agreement contained shall be construed as inconsistent with that status. The Contractor agrees to pay the contributions measured by the wages of his (its) employees required to be made under Unemployment Compensation Insurance, Social Security and Retirement Laws or similar laws, State or Federal, applicable to the work hereunder undertaken by the Contractor or his (its) subcontractors, and to accept exclusive liability for said contributions; the Contractor further promises and agrees to indemnify and hold harmless the Company, its successors and assigns, from any and all liability arising therefrom.

Pages 20–1–14 and 20–1–15: Renumber all existing sections on these pages because of the addition of new Sec. 1, and the combining of existing Secs. 11 and 12.

Pages 20–1–15: Eliminate existing Secs. 11 and 12 and substitute the following as new Sec. 12:

12. Insurance

The Contractor shall secure in the name of the Company, policies of insurance in amount, form and companies, satisfactory to the Chief Engineer, upon such structures and material as shall be specified by the latter, payable to the Company for the benefit of the Contractor or the Company as the Chief Engineer shall find their interests to appear.

(a) Workmen's Compensation insurance covering employees of the Contractor or any subcontractor, as required by the State or States in which the work is to be performed, so that the Company shall be fully protected from any liability or claims for damages for personal injury, including death, which may rise while engaged upon the work covered by this contract. The Contractor shall submit to the Chief Engineer evidence by certificate that such insurance in satisfactory amount is in force.

(b) Contractor's Public Liability insurance to cover bodily injuries, including death at any time resulting therefrom, with limits of $..... one person and $..... each accident, and damage to or destruction of property with limits of $..... each accident and $..... in the aggregate.

This policy shall be endorsed to cover contractual liability as contained in the indemnity provisions of this agreement and the collapse and explosion hazards in addition to all other hazards, unless such endorsements are waived by the Chief Engineer.

(c) Contractor's Protective Public Liability insurance, if there are one or more subcontractors, in the same amounts for bodily injuries (including death resulting therefrom) and for property damage as required in (b) above.

(d) Fire insurance, including extended coverage, in the name of and payable to the Company for the benefit of the Contractor or the Company as the Chief Engineer shall find their interests to appear. The policy shall cover such structures or structural material and supplies on hand and subject to damage by fire or storm, in such amount as necessary to cover their value.

Employees of the Company loaned or assigned to the Contractor, under the terms of this contract, for flagging and other protective service are to be considered employees of the Contractor for liability purpose.

Note. Railroad Protective Public Liability and Property Damage insurance may be desirable for or in addition to above.

All policies must be written by reliable and well rated insurance companies acceptable to the Chief Engineer. Certified copies of policies specified in clauses (b) and (c) shall be submitted to the Chief Engineer for approval before any work under this contract is commenced. When approved, they shall be retained by the Company, and the Contractor notified of their approval and authorized to enter on its property.

Said policies shall provide for notice to the Chief Engineer of the Company at least ..... days in advance of cancellation.

Page 20–1–16: Eliminate existing Sec. 13 and substitute the following as new Sec. 13.

13. Indemnity

The Contractor shall indemnify and save harmless the Company from and against all losses and all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description made, brought or recovered against the Company by reason of any act or omission of the Contractor, or his agents or employees, in the execution of the work, or in guarding the same.

Report on Assignment 3

Form of Lease Covering Subsurface Rights to Mine Under Railway Miscellaneous Physical Property

I. V. Wiley (chairman, subcommittee), J. P. Aaron, G. H. Beasley, R. G. Brohaugh, G. K. French, H. W. Legro, L. W. Lindberg, R. O. Nutt, J. L. Perrier, E. E. Phipps, H. L. Zouck.

Your committee has prepared a tentative form of lease covering this assignment and is now working on a revision of the form, which should be ready for presentation to the Association next year.

Report on Assignment 5

Insurance Provisions Recommended for Various Forms of Agreements

Clarence Young (chairman, subcommittee), K. A. Begemann, H. F. Brockett, R. G. Brohaugh, R. F. Correll, A. B. Costic, G. K. Davis, E. M. Hastings, Jr., R. C. Heckel, W. D. Kirkpatrick, C. B. Niehaus, W. E. Webb, D. J. White, D. H. Yazell.

This is a progress report, submitted as information.

There have been a number of developments in the controversial field of Railroad Protective Liability and Property Damage Insurance since your committee last reported on the subject. (Proceedings, Vol. 55, 1954, pages 421 to 426, incl.)

One of the developments arose out of Resolution 5 adopted by the American Association of State Highway Officials on November 11, 1954, at its annual convention at Seattle, Wash. The portion concerning insurance reads:

"WHEREAS, the Western Association of State Highway Officials appointed a special committee to study the matter of protective insurance required to be furnished to railroads on projects involving encroachment on railroad properties whether constructed in whole or in part with Federal highway funds; and

"WHEREAS the Western Association of State Highway Officials at its annual meeting in Sun Valley, Idaho, on September 18, 1954, resolved that the Western Association of State Highway Officials recommend that a conference be held by representatives of the American Association of State Highway Officials, Bureau of Public Roads, Association of American Railroads and insurance companies to work out a standard type of protective insurance which will provide adequate protection to the railroads, which can be written by American insurance companies and that Works Program General Memorandum No. 32, issued by the U. S. Department of Agriculture, Bureau of Public Roads, under date of January 27, 1937, be revised in accordance therewith; . . .

"RESOLVED, that a conference be held between a committee of the American Association of State Highway Officials, representatives of the Bureau of Public Roads, representatives of the Association of American Railroads, and representatives of insurance companies to work out a standard type of protective insurance which will be fair to the States and to Railroads, without excessively costly premiums, which can be written generally by insurance companies, and that said Memorandum No. 32 be revised in accordance therewith; . . ."

Conferences were held by the Committee on Grade Crossing Elimination of the Association of American Railroads, which were attended by members of the Insurance

Committee. Out of these conferences a form of "Railroad Protective Endorsement, Public Liability and Property Damage" was evolved. This form was sent to chief engineers of Member Roads by the Association on August 1, 1955.

On August 8, 1955, the Executive Committee of the American Association of State Highway Officials recommended that its Member Departments use the endorsement on a trial basis. On August 9, 1955, the commissioner of the Bureau of Public Roads advised the deputy commissioners and division engineers that General Memorandum No. 32 is amended and supplemented to the extent that the endorsement may be used. The endorsement reads as follows:

RAILROAD PROTECTIVE INSURANCE ENDORSEMENT PUBLIC LIABILITY AND PROPERTY DAMAGE

In consideration of the premium charged for the policy of insurance to which this endorsement is attached, it is further understood and agreed as follows:

1. That .....
is hereinafter referred to as the "Insured".

2. That the Insurance Company hereby agrees to pay to and on behalf of the Insured and indemnify the Insured against:

(A) All loss from the liability imposed upon the Insured by law for damages for bodily injuries (including death at any time resulting therefrom, and including care and loss of service) suffered or alleged to have been suffered by any person or persons (including, but not limited to, passengers and employees of the Insured), caused by, resulting from or in any manner connected with the prosecution of the work hereinafter described; and

(B) All loss from and liability for damage to or loss or destruction of property and loss of use thereof (including, but not limited to property owned, leased, occupied or used by, or in the care, custody and control of the Insured or any employees of the Insured), caused by, resulting from or in any manner connected with the prosecution of the work hereinafter described.

3. The Insurance Company hereby agrees:

(A) To defend in the name of and on behalf of the Insured any suit or action brought against the Insured seeking damages on account of any such bodily injury or death, or property damage, loss or destruction, even if such suit or action is groundless, false or fraudulent; provided, however, that the defense of any suit or action (or the prosecution of any subrogation rights) within the scope of the coverage of this policy, shall be handled in cooperation with the Insured if the latter so chooses.

(B) To pay, irrespective of the limits of liability stated in this endorsement, all costs, all premiums on attachment and appeal bonds taxed against the Insured or required in any such proceedings, all expenses incurred by the Insured, and all interest accruing after entry of judgment against such part thereof as shall not be in excess of the limits of the Insurance Company's liability until the Insurance Company has paid, tendered or deposited in court the amount of such judgment or such part thereof as does not exceed the limits of the Insurance Company's liability as expressed in this endorsement.

4. Description of the work: The Insurance Company hereby agrees that the work herein referred to shall mean all work and operations of the contractor hereinafter named

and its subcontractors, agents and employees, under or in connection with Contract No. ..... dated ..... between the State of ....., acting by and through ..... and ....., and any amendments
(Name of Contractor)
thereof and supplements thereto, for the performance of the following work:

.....
(Description of Work)

.....
(Location)

5. The Insurance Company hereby agrees that all exclusions in the policy of insurance to which this endorsement is attached are hereby deleted, but it is understood and agreed that this endorsement does not cover any liability or loss as a result of bodily injury or death, or property damage or destruction;

(A) Caused solely by the negligence of the Insured, its agents or employees.

(B) Suffered by any person or persons, or occasioned to any property, on account of whose injury or death or the damage or destruction of which the Insured shall have by agreement or otherwise voluntarily assumed or retained liability which, without such agreement, would not attach; provided, however, this endorsement shall cover any liability of the Insured arising from or as a part of any contract for the carriage of persons or property as a common carrier, and any liability as a bailee or otherwise of property, including rolling stock and equipment.

6. It is further understood and agreed that when employees of the Insured are loaned or assigned to the contractor or his subcontractors, to perform work in connection with his operations covered by this endorsement which is not in any way the work, business or operation of the trains of the Insured or is not done under direct control of the Insured, and if such employees of the Insured are subject to the direction and control of the contractor, his agents, employees or subcontractors, in all matters pertaining to their work, then for the purpose of this insurance such employees shall be regarded as employees of the contractor.

7. The limits of the Insurance Company's liability under this endorsement to the Insured are as follows:

	Each Person	*Each Occurrence*	*Aggregate*
Bodily injury and death coverage:	$.....	$.....	Not Applicable
Property damage coverage:	Not Applicable	$.....	$.....

8. Anything in the policy to which this endorsement is attached to the contrary notwithstanding, coverage provided under this policy is exclusive of any carried by the Insured, and coverages provided under this policy shall be exhausted first, notwithstanding the fact that the Insured may have other valid and collectible insurance covering the same risk.

9. Anything in the policy to which this endorsement is attached to the contrary notwithstanding, the policy shall not be cancelled, altered, amended or coverage reduced, without the giving of not less than thirty (30) days written notice by the Insurance

Company to the Insured and the State of ..... Acting by and through .....

10. Liability for payment of premiums under the policy to which this endorsement is attached, is solely upon the contractor named in paragraph 4 hereof.

11. Any of the provisions of the policy to which this endorsement is attached, inconsistent with this endorsement are hereby amended to conform with this endorsement, but, except as hereby modified and supplemented, the provisions of this policy shall be and remain in full force and effect.

This endorsement is to be attached to and forms a part of Policy No. ..... issued to ..... and shall become effective on the ..... day of ....., 19 ...., at the hour designated in said policy.

In Witness Whereof, the ..... Insurance Company has caused this Endorsement to be signed by its President; but the same shall not be binding upon the Company unless countersigned by its authorized agent.
Countersigned at ....
by:

....
Authorized Agent President

The proposed AAR–AASHO endorsement was submitted to the National Bureau of Casualty Underwriters and to Mutual Insurance Rating Bureau for comment. A joint meeting of the Railroad Protective Liability Subcommittees of the bureaus was held in New York on June 22, 1955, and their principal objections may be summarized as follows:

1. In the limited time allotted only a cursory analysis could be made of the proposal.
2. The endorsement is not written in insurance language.
3. The absence of "caused by accident" in the insuring agreements applicable to both bodily injury and property damage coverage.
4. The inclusion of direct property damage, including property owned by the railway. They point out that the railway has recourse to action against the contractor who, presumably, would be required to carry Contractors' General Liability Insurance.
5. The provision for defense of claims to be handled in cooperation with the insured. They maintain that the insurance company's money is at stake and that it should have the right of investigation, defense and settlement of claims.
6. The absence of exclusion of any obligation for which the railway may be held liable under any Workmen's Compensation Act. They point out that this would involve a violation of the insurance laws in practically every state. From a practical standpoint such exclusion would have little significance as most railways are interstate and not subject to state workmen's compensation laws.
7. The absence of completed operations exclusion.

The subcommittees of the insurance bureaus submitted a form of endorsement which they worked out in cooperation with the State of New York over a period of months. This form will be incorporated in all contracts involving railroads let by the Department of Public Works, State of New York. The New York form reads as follows:

RAILROAD PROTECTIVE LIABILITY INSURANCE

NEW YORK STATE DEPARTMENT OF PUBLIC WORKS PROJECTS

Coverage

The policy shall cover the liability imposed upon the insured (railroad company) by law for damages, including damages for care and loss of services, because of bodily injury, sickness or disease, including death at any time resulting therefrom, sustained by any person or persons, and damages because of injury to or destruction of property, including the loss of use thereof, caused by accident and arising out of any acts or omissions of the following in the performance of any operations under the contract for the designated project:

1. The contractor and his subcontractors;
2. Flagmen, watchmen, and other protective employees, other than those specified in (3) and (4) below, specifically loaned or assigned by the insured to the work performed by the contractor or his subcontractors, provided the cost of service of such employees is specifically to be paid for or borne by the contractor or subcontractor or by a governmental authority;
3. Supervisory employees of the insured while performing services, at the job site, with respect to the operations of the contractor or his subcontractors;
4. Employees of the insured while operating, attached to, or engaged on, at the job site, work trains or other railroad equipment exclusively assigned to the contractor or his subcontractors by the insured;

provided, however, that a proximate cause of the accident is an act or omission of any individual included in (1), (2), (3) or (4) above.

The policy shall also cover the liability imposed upon the insured by law for damages including damages for care and loss of services, because of bodily injury, sickness or disease, including death at any time resulting therefrom, caused by accident and sustained at the job site by any employee of the contractor or his subcontractor.

The terms "contractor" and "subcontractor" shall not include the named insured.

Exclusions

1. Any obligation for which the insured or any carrier as his insurer may be held liable under any workmen's or unemployment compensation, disability benefits or similar law.
2. Any liability assumed by the insured under any contract or agreement other than contracts of carriage as a common carrier. Contracts of carriage as a common carrier as used herein shall not include those between the insured and the contractor or his subcontractors.
3. Any liability arising out of accidents occurring after operations have been completed or abandoned at the place of occurrence thereof, other than accidents caused by the existence of tools, uninstalled equipment and abandoned or unused materials, but operations shall not be deemed incomplete because improperly or defectively performed or because further operations may be required pursuant to a service or maintenance contract. This exclusion does not apply until the state notifies the insured of acceptance of the project.
4. Injury to or destruction of property owned by the insured.

The Executive Committee of the American Association of State Highway Officials recommended the approval of the AAR form on a trial basis to determine if favorable insurance rates can be secured, to promote uniform procedures and to expedite agreements between state highway departments and railways. If the rates are too high for the broad coverage required by the AAR form, there is no doubt that the AASHO and the Bureau of Public Roads will insist on some modification, perhaps in line with that prescribed by the Department of Public Works of New York State.

Report on Assignment 6

Form of Agreement for Turnpike or Toll Road Crossing Railway Tracks and Property

J. W. Wallenius (chairman, subcommittee), J. P. Aaron, K. A. Begemann, H. F. Brockett, R. F. Correll, A. B. Costic, G. K. Davis, C. L. Gatton, R. C. Heckel, J. F. Halpin C. J. Henry, D. F. Lyons, J. W. McMillen, W. L. Mogle, G. W. Patterson, J. L. Perrier, W. R. Swatosh, W. E. Webb, D. H. Yazell, Clarence Young.

Your committee submits the following tentative draft of agreement as information.

The Manual does not contain a form of agreement covering turnpike or toll road crossings. Hence, with the great increase in the number of crossings of this type, it was felt desirable to have a form of agreement to cover such crossings.

Members of the Association are requested to give the committee the benefit of their suggestions and criticisms.

FORM OF AGREEMENT FOR TURNPIKE OR TOLL ROAD CROSSING RAILWAY TRACKS AND PROPERTY

THIS AGREEMENT, made this ..... day of ....., 19..., by and between ....., a corporation organized and existing under the laws of the State of ....., hereinafter called the Railway Company, and the ....., a body politic and corporate established by law by the State of ....., hereinafter called the Authority.

WITNESSETH:

WHEREAS, the Authority is engaged in the construction of a highway from a point at or near ....., to a point at or near .....; and

WHEREAS, the Authority, in connection with the construction of said highway, desires to cross (over) (under) the property, right-of-way, tracks and facilities of the Railway Company at or near ....., by means of a grade separation structure designated Highway Structure No. ....., and hereinafter called Crossing Project; and

WHEREAS, the Railway Company and the Authority, pursuant to certain preliminary negotiations now desire to enter into an Agreement, in writing, setting forth the terms and conditions under which the crossing project shall be constructed and thereafter maintained or removed;

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. Plans and Specifications

The location and general arrangement of the crossing project shall conform to the layout shown on plan marked Exhibit "A" bearing the title ..... and date ....., which is identified by the initials ....., attached hereto and made a part hereof.

The Authority, at its own expense, shall prepare detailed plans and specifications for the complete crossing project, and shall submit all such plans and specifications bearing the approval of the Chief Engineer of the Authority to the Chief Engineer of the Railway Company for his approval. Such plans and specifications may be modified and supplemented by additional plans and specifications, provided that such modifications and supplemental plans and specifications are first approved by the respective Chief Engineers of the parties hereto. Approval of all plans and specifications shall be noted thereon in writing by the Chief Engineers of the parties hereto. Where the Chief Engineer of the Railroad Company is specified, it shall mean such person as he may designate.

2. Work By the Authority

After approval of the detailed plans and specifications by the Railway Company, the Authority, at its own expense, shall contract for and cause to be performed in accordance therewith, all work in connection with the construction of the entire crossing project, excepting, however, work to be performed by the Railway Company as hereinafter set forth in Sec. 3.

3. Work By Railway Company

The Railway Company will, but at the expense of the Authority, furnish all materials and equipment, and perform all work, both temporary and permanent, in connection with any adjustment of any Railway facilities which may be or become necessary in the course of the construction of the crossing project. This work may be performed by the Railway Company with its own forces, or should it so elect, the Railway Company may have all or any part performed by contract; any contract which the Railway Company may elect to enter into in respect to the alteration of its facilities shall first have the approval of the Chief Engineer of the Authority.

4. Payment for Work

The Authority shall reimburse the Railway Company for all cost incurred by it, connected with the crossing project, including, but not limited to, the following:

(a) Costs of all surveys, including preliminary, preparation and checking of plans, estimates and specifications, expenses of all inspection during the progress of the work, including wages, salaries and expenses paid the Railway Company employees (exclusive of general supervisory personnel) directly engaged in surveys, plan preparation and progress inspection, plus ..... percent of such wages and salaries as reimbursement for the costs of supervision and administration.

(b) All costs arising under any contract for any portion of the work, provided said contract has been approved by the Chief Engineer of the Authority, plus ..... percent for accounting and supervision.

(c) All costs for labor furnished directly by the Railway Company, including all wages, salaries and expenses paid by the Railway Company to its employees (exclusive of general supervisory personnel) engaged in the work, plus ..... percent of such labor costs as reimbursement for the costs of supervision and administration.

(d) All costs for materials furnished by the Railway Company, plus stores expenses at the rate of ..... percent of the value of materials furnished by the Railway Company's Stores Department, and purchase expense at the rate of ..... percent on the cost of materials furnished through the Railway Company's Purchasing Agent as reimbursement for the costs of handling, supervision and administration.

(e) All costs of Workmen's Compensation or Employer's Liability insurance and Federal Employers Liability, Fire Insurance, Public Liability, Railroad Protective Liability and Property Damage insurance.

(f) All applicable taxes levied on any materials purchased for the work.

(g) Rental of tools, equipment and machinery (including locomotives and work trains), rolling stock and roadway machines furnished by the Railway Company at established rental rates.

(h) Cost of bond premiums and cost of fees for all permits and licenses.

(i) Vacation allowances and all taxes, federal and state, based on compensation by the Railway Company to employees engaged in the work.

(j) Cost of transportation for materials and equipment over the Railway Company's lines, as well as over other railway lines, at current commercial rates.

(k) Such other items of expense as may be agreed upon by the Chief Engineer of the Railway Company and the Chief Engineer of the Authority.

The Railway Company shall be reimbursed by the Authority monthly upon receipt of properly certified invoices (No. of copies). If such invoices are not approved by the Authority, it shall notify the Railway Company within ten days after receipt and any objections shall be resolved as promptly as possible.

Upon completion of all work performed by the Railway Company, and within ..... days following the receipt of certified invoices covering such completion, the Authority shall make final and complete payment to the Railway Company.

If requested by the Authority, the Railway Company will furnish evidence and permit examination of its records pertaining to the crossing project from which the invoices have been prepared.

5. Insurance

The Authority shall require its contractor to take out insurance as hereinafter provided prior to the commencement of the work and to keep the same in effect until all the work provided for herein is completed.

Said insurance shall protect the contractor and his subcontractors from liability and claims for damages for bodily injury, including wrongful death, and for damages to property caused by any accident arising from the contractor's or any subcontractor's performance of the work which he has contracted to perform.

Said insurance need not cover any liability or claims for damages: (1) for personal injuries to, or sickness, disease, or death of any employee of the contractor while engaged in the employment of the contractor; (2) arising from the use or loading or unloading of aircraft or watercraft; (3) for loss of, or damage to, property owned or leased by the insured or in his care, custody, or control; or (4) for injury to, or destruction of, wires, conduits, pipes, mains, sewers, or other similar property, or any apparatus in connection therewith, below the surface of the ground, if the same be caused by and occur during the use of mechanical equipment for the purpose of excavating or drilling. It need not cover any obligation for which the contractor or any insurance company as his insurer may be held liable under any Workmen's Compensation Law. It must cover

liability and claims arising from the use and operation, anywhere in the United States, in connection with the performance of said work, of automobiles as customarily defined in liability-insurance policies, whether they be owned or non-owned by the contractor.

Said insurance shall be in the following amounts:

(a) Insurance in an amount of not less than ..... for injuries, including those resulting in death, to any one person, and in an amount of not less than .... on account of any one accident.

(b) Insurance in an amount of not less than ..... for damages to or destruction of property on account of any one accident, and in an amount not less than ..... in the aggregate during each policy period, each of which shall be not longer than one year.

The Railway Company may take out insurance which will protect and save harmless the Railway Company from and against: (1) all loss of and damage to any property whatsoever (including property of the parties hereto and of all other persons whomsoever and the loss of or interference with any use or service thereof); (2) all loss and damage on account of injury to or death of any person whomsoever (including employees and patrons of the parties hereto and all other persons whomsoever); and (3) all claims and liability for such loss and damage and cost and expense thereof caused by, growing out of, or in any way related to or connected with the construction of the bridges and drainage system provided for by this agreement, whether or not caused by the negligence of the Railway Company. Such insurance may provide coverage limits in such amounts as the Railway Company may determine. The cost of such policies shall be considered as a part of the costs of the Railway Company for which it shall be entitled to reimbursement, but in no event shall the aggregate cost of such policies exceed ..... The Railway Company hereby waives all claims against the Authority arising out of any tort to the extent that the Railway Company is protected by such policies. In the event companion policies are issued to the Authority, as insured, the cost of such companion policies shall be paid to the insurance company by the Railway Company, and the Railway Company shall be reimbursed therefor by the Authority.

6. Protection of Railway Traffic During Construction

(a) The Authority agrees that the safety and continuity of the operation of the traffic of the Railway Company shall be of first importance and shall be at all times protected and safeguarded. The Authority shall require its contractor to perform and arrange its work accordingly. Whenever, in the judgment of the Chief Engineer of the Railway Company or his representatives, the work or its performance may affect or involve the safety of the Railway Company's facilities and operation of its railway, the method of doing such work shall first be submitted to the Chief Engineer of the Railway Company for his approval, without which it shall not be commenced or prosecuted. The approval of the Chief Engineer of the Railway Company, when given, shall not be considered as a release from responsibility or liability for any damage which the Railway Company may suffer, or for which it may be held liable, as a result of the acts of the contractor or their subcontractors or their employees.

(b) The Authority shall require its contractor to give written notice to the Chief Engineer of the Railway Company not less than ..... days in advance of the commencement of work on or over the Railway Company's right-of-way, in order that the Chief Engineer of the Railway Company may make the necessary arrangements promptly for the protection of the Railway Company's operation.

(c) When deemed necessary by the Railway Company, it may assign or employ an Inspector(s) or Engineer(s), who will be placed on the work during the time the Authority's contractor is performing the construction provided for herein. The Authority shall reimburse or cause the Railway Company to be reimbursed for the cost and expense of such Inspector(s) or Engineer(s).

(d) Whenever in the opinion of the Railway Company the construction may cause a hazard to the safe operation of the Railway, the Railway Company may place at the site of the work the required number of qualified employees to protect its operation. The providing of such employees and such other precautions as may be taken shall not relieve the Authority or its Contractor or subcontractors from liability for the payment of damages caused by their operations, and for the purpose thereof such employees of the Railway Company shall be considered as employees of the contractor or subcontractor. The Railway Company shall be the sole judge of necessity, number and classification of employees required. The Authority shall arrange for the prompt reimbursement to the Railway Company for all cost and expense of providing such employees.

7. Mutual Consultation and Cooperation

It is understood and agreed between the Railway Company and the Authority that each shall conduct its work, or cause its work to be conducted in such a manner as not to unduly impede the work of the other, and that they shall confer with each other with respect to the various parts of the work before and during the progress of same for the purpose of preventing interference or delays and securing full cooperation in the expeditious handling of the crossing project. Each shall, upon notice from the other of any default or failure of any party, firm or corporation performing work under contract with respect to any part of this crossing project, promptly proceed to secure full compliance with the approved plans and specifications.

It is expressly understood and agreed that the highway crossing project includes no work for which the Railway Company is to be billed by the Authority. It is further understood and agreed that the contractor for the Authority shall not bill the Railway Company for any work which it may perform, unless the Chief Engineer of the Railway Company shall have given a written request to the contractor for such work to be performed at the expense of the Railway Company.

8. Future Attachments to Crossing Structure

The Railway Company shall have the right, at its own cost and expense, but subsequent to the initial attachments, which are a part of this project, and paid for by the Authority, to attach to the crossing structure from time to time, and to thereafter maintain, change, repair and renew, without charge therefore by the Authority, such equipment, signal, telephone, telegraph, power or transmission wires, cables, conduits and pipes, or other facilities as may be requisite or useful in the operation of the Railway Company, provided, however, that the manner and method of attachment shall first be submitted to and have the approval of the Chief Engineer of the Authority and shall be of such character as not to interfere with the safety, operation or maintenance of the highway crossing structure.

9. Future Maintenance of Facilities

The Railway Company agrees that, after completion of the said crossing structure and acceptance of the same by the Authority, the Railway Company will, at its own expense, maintain, repair and renew all of its railway facilities, including, but not

restricted to, signals, communications and power lines which may be affected or relocated by reason of the crossing structure. The Authority agrees, at its own expense, to own, maintain, repair and renew the entire bridge structure, its approaches, substructure and superstructure, appurtenances, and the sidewalk and the roadway then or after located on the crossing structure, approaches and the drainage system, all of which shall be and remain the property of the Authority; the Authority further agrees to keep said highway crossing structure in a suitable, safe and secure condition, so as not to impede, jeopardize or interfere with the full, free and safe use, operation and enjoyment by the Railway Company of its railroad appurtenances and property, as the same may now or hereafter exist. In any event, the Authority shall, if requested by the Railway Company, make such repairs and renewals as may be reasonably necessary to keep the crossing structure in such suitable, safe and secure condition. If the Authority shall fail or neglects to do so, the Railway Company shall have the right, on reasonable notice, to do so, and the Authority shall promptly reimburse the Railway Company for its cost and expense therefor. Nothing in this Agreement shall release either party from claims for damage caused to the property of the other party.

10. Right of Entry and Grant of Easement

The Railway Company will permit the Authority to enter upon the property of the Railway Company to the extent reasonably necessary for inspection, construction, maintenance, repair and renewal of the crossing structure, provided, however, that the Authority shall give reasonable advance notice to the Railway Company of any work proposed to be done which is likely to interfere with the safety and operation of the Railway Company or other rights or interests in or to its property. Such work shall be done in such manner and under such conditions as not to interfere with the proper, safe and continuous use, operation and enjoyment of the property and railway of the Railway Company; if requested by the Railway Company, the Authority shall submit plans and specifications to the Railway Company for its acceptance and approval before any maintenance work is started; the Authority shall require its contractor to secure insurance coverage in favor of the Railway Company as may be necessary in view of the work to be performed, and such work shall be accomplished in accordance with the terms of this Agreement.

The Railway Company agrees, insofar as its title enables it to do so, and subject to the right of the Railway Company to continue to operate its railway (over) (under) said crossing structure, that it will grant and convey to the Authority, its successors and assigns, an easement in perpetuity for the construction, reconstruction, maintenance, repair, renewal and operation, and use upon its lands, of the highway crossing structure, its foundations and supports, which shall be constructed in the manner and location as provided by the terms of this Agreement, and as set forth on the property plan and map designated Exhibit "B" bearing the title "Parcel Easement Plan, ..." which is attached hereto and made a part hereof, or any revision thereof which may be agreed to by the above parties hereto.

11. Future Crossing Privilege by the Railway Company

If at any time the Railway Company should desire to cross the facilities of the Authority, either above or below their grade, with a facility for the purpose of extending its railroad tracks or facilities, the Authority, as part consideration hereof, and the futher consideration that the Railway Company is not requiring the Authority to pay compensation for the use and occupation of the land and property of the Railway Com-

pany in the construction of this crossing structure, as well as certain other crossing structures of the Authority, shall grant the Railway Company the right for such crossings without charge therefor; provided, however, that all costs and expense of effecting such crossing shall be paid by the Railway Company and that the work shall be accomplished so as not to interfere materially with the use and operation of the facilities of the Authority, and that the plans and specifications therefor are submitted to and approved by the Authority before work is commenced, and that insurance coverage as may be necessary, in view of the work to be performed, is furnished the Authority, and provided that conditions similar to those imposed herein for the crossing of the right-of-way and track of the Railway Company by the structure of the Authority, are made in a manner mutually satisfactory to the Railway Company and the Authority.

12. Indemnity

The Authority shall indemnify and save harmless the Railway Company from and against all losses and all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description made, brought or recovered against the Railway Company by reason of any act or omission of the Authority, its agents or employees, in the execution of the work or in guarding the same.

In case no bond is furnished, the Railway Company may require indemnity insurance in amount, form and substance, satisfactory and acceptable to the Railway Company, which insurance shall provide for the protection of the Railway Company against failure of the Authority to comply with the conditions of this covenant. The Authority shall take out and pay the premiums on such insurance.

13. Disputes and Arbitration

Except as otherwise provided, all disputes concerning questions of fact arising in this Agreement shall be decided by the Chief Engineer of the Railway Company and the Chief Engineer of the Authority.

In case any question arises under this Agreement, or concerning the subject matter thereof, upon which the parties hereto can not agree, such questions shall be settled by a sole, disinterested arbitrator, to be selected jointly by the parties of this Agreement within ..... days of receipt of request for arbitration made by either party. The expense of the arbitration shall be borne between the parties hereto, or wholly borne by either party, as determined by the arbitrator.

14. Licenses and Permits

The Authority shall obtain all required licenses, permits or orders from the Public Utility Commission of the State of ....., federal, state and local authorities, as may be required for the prosecution of the highway crossing project, except as otherwise provided in Sec. 4, Paragraph (h).

15. Duration and Succession

The terms and conditions of this Agreement shall inure to the benefit of and be binding upon the parties hereto, their respective successors and assigns.

In Witness Whereof, the parties hereto have executed this contract, in .....
....., the day and year first above written.

..... Railway Company

By .....

Attest:

.....
Secretary

..... Authority

By .....

Witness:

.....

Report of Committee 14—Yards and Terminals

J. N. Todd, *Chairman*

F. A. Hess, *Vice Chairman*,
H. L. Scribner, *Secretary*,
M. H. Aldrich
F. E. Austerman
R. F. Beck
A. E. Biermann
W. O. Boessneck
W. S. Broome
N. C. L. Brown
W. P. Buchanan
J. C. Bussey
J. G. Campbell
G. H. Chabot
R. S. Cheney
H. P. Clapp
K. L. Clark
Oscar Fischer
H. C. Forman
S. W. George
B. F. Gilbert
W. H. Giles
W. H. Goold
H. J. Gordon
J. E. Griffith
G. F. Hand (E)
L. C. Harman
Wm. J. Hedley
H. W. Hem
J. E. Hoving
M. A. James
V. C. Kennedy
A. S. Krefting
B. Laubenfels
E. K. Lawrence
Glen Lichtenwalner
J. L. Loida
L. L. Lyford (E)
H. J. McNally
C. E. Merriman
C. J. Morris
C. H. Mottier
H. F. Moy
A. G. Neighbour
B. G. Packard
C. F. Parvin
R. H. Peak
L. F. Pohl
C. L. Richard
G. L. Roberts
L. W. Robinson
R. E. Robinson
H. T. Roebuck
M. S. Rose
H. H. Russell
W. C. Sadler
W. H. Shoemaker
R. A. Skooglun
R. F. Straw
P. P. Wagner, Jr.
J. C. Warren
J. W. Weiffenbach
C. F. Worden
G. R. Wurtele

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 364

2. Classification yards, collaborating with Committee 16.
   Final report on track connections, presented as information ..... page 365

3. Scales used in railway service.
   Part 1—Specifications for Manufacture and Installation of Four-section Motor Truck Scales, submitted for inclusion in the Manual ..... page 369
   Part 2—Progress report on weighing freight cars by the two-draft method, presented as information ..... page 369
   Part 3—Progress report on electronic scales, presented as information ..... page 370

4. Waterfront terminals.
   Final report, presented as information ..... page 370

5. Influence of roller bearing cars on design of hump and flat yards.
   No report.

6. Facilities for loading and unloading highway semi-trailers on railroad cars, collaborating with Committees 6 and 16.
Final report, presented as information ..... page 373

7. Design data for classification yard gradients.
No report.

8. (a) Location and design of car repair tracks and facilities in relation to classification yards.
Final report, presented as information ..... page 374
(b) Location and design of engine servicing tracks and facilities in relation to classification yards.
Final report, presented as information ..... page 375

9. Procedure for analyzing hump yard operations.
No report.

The Committee on Yards and Terminals,
J. N. Todd, *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 1

Revision of Manual

W. H. Goold (chairman, subcommittee), F. E. Austerman, A. E. Biermann, W. S. Broome, J. C. Bussey, G. H. Chabot, H. C. Forman, W. H. Giles, Wm. J. Hedley, L. L. Lyford, C. E. Merriman, C. H. Mottier, A. G. Neighbour, H. L. Scribner, J. N. Todd.

Your committee offers for adoption the following recommendations with respect to the Manual.

Pages 14–2–1 to 14–2–19, incl.

PASSENGER TERMINALS

Page 14–2–8:

Change the word "minimal" to "minimum" in the first line of Par. (e), Art. 10.

Delete Par. (f), Art. 10, and substitute the following:

(f) Exclusive trucking platforms without columns should have a minimum width of 11 ft to permit 2 trucks to pass. Where the volume of trucking is sufficient to justify 3 lanes, a minimum of 16 ft should be provided to avoid blocking the platform when 2 trucks are serving cars on opposite sides. If columns are necessary, platform widths should be increased accordingly and columns located so as not to interfere with trucking lanes.

Substitute the words "clear width" for the word "clearance" in the second line of Par. (g), Art. 10.

Delete Par. (h), Art. 10, and substitute the following:

(h) In stations where a large number of passengers must be handled quickly, the relation of platform elevation to height of car floor should be considered to expedite the handling of passengers. However, high platforms interefere to some extent with the switching and inspection of equipment.

Delete Par. (j), Art. 10, and susbtitute the following:

(j) In large metropolitan areas, the character and volume of arriving mail may justify separate mail handling facilities incorporating the use of belt conveyors.

Page 14–2–9:

In Par. (b), Art. 11, delete the words "for heights less than 25 ft". Also, substitute the word "stairways" for the word "stairs".

Delete Par. (c), Art. 11.

Change present Par. (d), Art. 11 to Par. (c).

Delete present Par. (e), Art. 11, and substitute the following:

(d) Moving stairways have a maximum carrying capacity of approximately 5000 passengers per hour for 32-in width and 8000 passengers per hour for 48 in. They are being used successfully in both suburban and through passenger service.

In Par. (a), Art. 12, change the first sentence to read "Ramps provide ideal means for movement of passengers to and from station platforms if they can be so installed . . ." (remainder of sentence unchanged). In last sentence, change the word "stairs" to "stairways" and delete the words "in the approach to the platform".

Delete Par. (b), Art. 13, and substitute the following:

(b) Ramp gradients in excess of 8 percent are not recommended.

Page 14–2–13:

In the third line of Par. (a), Art. 1, delete the words "including streamline trains".

Page 14–2–16:

In Par. (h2), Art. 2, add after the second sentence the following sentence: "Frost protection should be provided where necessary".

In Par. (I1), delete the first three sentences and substitute the following:

1. Where underneath inspection of standing cars is desired, one or more pits equal in length to the longest train may be justified. These may be combination inspection and repair pits depending on their location in the yard. If underneath inspection of cars in motion is desired, a short pit located on the yard lead or the mechanical washer track may be used.

Report on Assignment 2

Classification Yards

Collaborating with Committee 16

C. E. Merriman (chairman, subcommittee), M. H. Aldrich, R. F. Beck, A. E. Biermann, W. S. Broome, N. C. L. Brown, J. C. Bussey, R. S. Cheney, H. P. Clapp, Oscar Fischer, H. C. Forman, W. H. Giles, W. H. Goold, H. J. Gordon, J. E. Griffith, J. E. Hoving, B. Laubenfels, Glen Lichtenwalner, J. L. Loida, L. L. Lyford, H. J. McNally, C. J. Morris, R. H. Peak, Jr., L. W. Robinson, H. T. Roebuck, M. S. Rose, W. C. Sadler, R. A. Skooglun, J. N. Todd, J. C. Warren, C. F. Worden.

Track Connections Between Receiving, Classification and Departure Yards

This is a final report, submitted as information.

General

Track connections which should be provided between the receiving, classification and departure yards in a hump yard layout will depend on the relative position of these yard elements.

In the Proceedings, Vol. 55, 1954, page 429, is a report on nine basic arrangements of receiving and departure yards in relation to hump classification yards. This present report makes no effort to cover all connections that might apply to each of the nine arrangements; instead, an attempt is made to cover, in a general way, such connections as are usually required irrespective of the plan.

Tracks Between Receiving and Classification Yards

1. Road Engine Escape Tracks

A series of crossovers near the center of the longer receiving tracks will frequently allow prompt escape of road engines and will also facilitate doubling or consolidating short cuts for movement to the hump.

The track arrangement of the hump end of the receiving yard should be given special consideration to provide the least possible interference between humping and road engines going to the engine servicing facilities. Alternate avenues of escape should be provided if possible.

Tracks connecting the hump end of the receiving yard with the engine servicing facilities should be as direct as possible.

2. Humping Leads

The lead between the receiving yard and the hump crest should be as short as possible.

Where it is not practical to bring the receiving yard reasonably close to the hump crest, it is usually desirable to carry two approach leads up as close to the hump crest as the layout will permit. This will allow bringing a cut of cars into a position ready for humping as soon as a preceding cut is completed.

Two independent humping leads are sometimes constructed over the crest to meet special conditions. When they are, a double crossover is usually provided between the two leads just beyond the hump crest. Such an arrangement will permit simultaneous humping on each lead to a portion of the classification yard, or from either single lead to any classification track.

As a rule, to obtain any advantage from simultaneous humping, it is necessary that the trains being humped at one time have very few, if any, cars of the same classification.

3. Inspection Pit—Journal Oiling

If the plan is to include moving inspection and journal oiling at the hump, track connections should be arranged accordingly. The inspection pit should be at least 180 ft ahead of the hump crest, and the track over it should be straight for a car length either side, if possible.

4. Set-Out Track

A track out of the humping lead near the crest of the hump is desirable for setting out cars which are not to be humped. Such a track, stub ended if desired, should be provided if the layout does not have some other track out of the hump lead which can be used for this purpose. The turnout should, of course, be facing point to humping movement and preferably to the left so it will not present a footing obstacle to the pin puller or obstruct his view. The track should have enough level grade just behind the turnout to accommodate several cars if conditions will permit.

5. Classification Leads

Classification tracks should be arranged in groups, with sub-leads connecting each group to the main leads down the hump. Group arrangement reduces the number of retarders required and also reduces the distance from crest to clearance on classification tracks.

6. Pull-Back Track

A pull-back track may be located on either side of the humping lead, connecting one or more outside group leads near the base of the hump with tracks approaching the hump. Such tracks are helpful in pulling or doubling classification tracks from the hump end while humping continues to other parts of the yard, and also serve as escape routes for the hump locomotive which can move down the hump following the last car and return to the receiving yard while a closely following train is being pushed to the crest. Such an escape for the humping engines is especially desirable where other routes above mentioned are not available.

7. Inbound Lead at Hump End of Receiving Yard

In some yards, especially those with a single hump, it is generally necessary to have some trains enter the receiving yard at the hump end. Regardless of whether receiving and classification yards are side by side or end to end, special care is necessary in designing the track layout at the hump end of the receiving yard and connections with the hump in order to hold to the minimum the possibility of conflicting movements.

8. Run-around Tracks

Open thoroughfare tracks around one, if not both, sides of the entire yard, with appropriate connections at the hump, are desirable. Inbound or outbound leads can, in some instances, be used for this purpose.

9. Engine Servicing and Parking Track

At some yards, especially where the humping crews go on and off duty at the hump, a track is constructed nearby on which hump locomotives can be parked during the crew's lunch period and for fueling and servicing. The track should be provided with fixed engine servicing facilities or have a roadway alongside for mobile servicing.

10. Icing Facilities

Tracks connecting the icing facilities directly to the hump and the departure yard are usually desirable regardless of whether refrigerators are iced before or after classification.

11. Hump By-Pass

In yards where certain inbound trains are not to be humped, a track should be provided which will permit them to by-pass the hump and move directly from the receiving yard to the departure yard.

Tracks Between Classification and Departure Yards

1. Ladder Tracks

In order to reduce engine travel, maximum lead angles are desirable in the ladder tracks at the lower end of the classification yard.

2. Switching Leads or Tail Tracks

Ladder tracks should connect with two or more switching leads or tail tracks. The number of lead or tail tracks preferably should be one more than the maximum number of pull-down engines that are to work at one time. The leads should be interconnected as close to the throat of the classification yard as possible, so that any yard track can be reached from any lead.

The track arrangement between the classification yard and the departure yard will vary with their relative positions, i.e., end to end with connecting leads, or with departure tracks along one or both sides of the classification yard, calling for a pull and shove operation. In any case, crossovers and connections should be located to obtain flexibility and the shortest engine movement possible.

Tail tracks should be long enough in the clear of the switch to departure tracks to handle the longest classification track. They should also be long enough to switch bad order cars out of a train which has been made up.

Track arrangement at the lower end of the classification yard should be such that pull-down operations will not interfere with train movements entering or leaving the yards.

3. Crossovers in Departure Yard

Crossovers may be provided near the center of the departure yard, especially between the long tracks. These crossovers will not only assist materially in switching bad orders out of the middle of trains about to depart, but will make the assembling operation more flexible and have the effect of increasing the yard's capacity.

4. Car Repair Yard

Connection to the car repair yard should be as direct and short as possible, to permit switching out ready cars several times a day, if necessary, and also to expedite special handling of individual loads to order to get them into outbound trains or transfers. Connections should be so arranged that switching the repair yard will not interfere with pull-down movements.

5. Turning Tracks

In yards where it is necessary to turn engines, a loop or wye track should be provided in a convenient location.

6. Weighing

In yards where spot weighing is done, tail track room in the clear of other operations and with proper connections to both the hump and departure tracks should be provided.

7. Caboose Tracks

Caboose tracks should be at a location convenient to outbound train assembly and where they are readily accessible by roadway for servicing and boarding. Connections with both ends should be as direct as possible. The number of caboose tracks and arrangement of connections with the switching leads will depend on separations desired, radio equipment if any, and whether or not the road cabooses are pooled.

8. Cleaning Tracks

Where cleaning tracks are required, appropriate connections for setting, pulling and rehumping should be included in the plan.

9. Servicing Track for Pull-Down Engines

A servicing track for pull-down engines is frequently provided at a location central to their operations. Fueling, servicing and daily inspection can be made during a lunch period or when crews change. Such a track is essential if crews go on and off duty at this location. Like a similar track suggested at the hump, it should have fixed servicing facilities or be served by a road alongside for a mobile servicing unit.

10. Small Auxiliary Yards

A yard layout may require any of the following small auxiliary yards:

a. Local make-up.
b. Interchange.
c. Grain, hold for inspection and forwarding instructions.
d. Storage.
e. Produce terminal or team yard.
f. Maintenance of way.
g. Trailers on flat car yard.

Appropriate connections and switch tail room to serve these yards should be provided.

11. Route from Engine Servicing Facilities

Plan should provide an open route for road engine movements between the engine servicing facilities and the leaving end of the departure yard.

12. Inter-Yard Connections

A yard with two humps will require tracks cross connecting the humps and departure yards for consolidating cars of the same classification and for other movements of a similar nature.

Report on Assignment 3

Scales Used in Railway Service

Collaborating with Electrical Section, AAR

C. L. Richard (chairman, subcommittee), W. P. Buchanan, G. H. Chabot, B. F. Gilbert, H. W. Hem, J. E. Hoving, V. C. Kennedy, E. K. Lawrence, H. H. Russell, R. F. Straw, J. N. Todd, J. W. Weiffenbach.

Part 1

Specifications for the Manufacture and Installation of Four-Section Motor Truck Scales

Last year your committee presented as information a tentative draft of Specifications for the Manufacture and Installation of Four-Section Motor Truck Scales (Proceedings, Vol. 56, 1955, pages 394 to 410, incl.) and invited comments and criticisms thereon. These specifications, with the following revisions, are now submitted with the recommendation that they be adopted and published in the Manual.

Page 398, Sec. C, Art. 13: In the pressure values shown, change psi to lb per sq ft.

Page 400, Sec. CC, Note 2 following Table 4: At beginning of the sentence, change "section" to "section load".

Page 400, Sec. D, Art. 2: Change first sentence to read: Castings, steel tubing or structural steel shapes used for levers shall not be warped.

Page 408, Sec. LL, Art. 4, Table 5: In first line of Floorbeam data change 31.8 lb to 36.0 lb in last two columns. In the second line of Floorbeam data change 3498 to 3960 lb in the first column, change 3816 to 4320 lb in the second column, and change 4452 to 5040 lb in the third column. In the first line of Total data change 10263 to 10725, 11791 to 12295, and 15439 to 16027. In the second line of Total data, last column, change 15739 to 16327.

Part 2

Weighing Freight Cars by the Two-Draft Method

Your committee offers the following report as information on the subject "Weighing Freight Cars by the Two-Draft Method".

In recent years experimental studies were conducted on some railways to determine whether the gross weight of loaded freight cars could be obtained satisfactorily by separately weighing the individual trucks of a car and adding the results to represent the total car weight. The method has now been adopted at many weighing points on

American railways and at two points on one Canadian railway, principally for weighing cars of coal, ore, sand or gravel while in motion.

Data reported to the committee indicate that with a well installed and properly maintained scale, and with appropriate control over weighing operations, satisfactory results are obtained. The advantage of the method is that it permits the use of a short scale (12 to 20 ft) costing considerably less than one of conventional length. Essential requirements are that the levers and weighbridge be of substantial construction, that the approach and run-off rails be maintained in precise surface alinement with the weigh rails, and that movement of the cars over the scale be at moderate and uniform speed.

Your committee will continue to study the subject.

Part 3

Electronic Scales

Last year your committee submitted a report summarizing information and opinion regarding the use of electronic scales for weighing freight cars (Proceedings, Vol. 56, 1955, page 1019). The committee now reports, as supplementary information, that a few new electronic track scales have since been installed or are scheduled for installation by railways or industries, that some new developments in the instrumentation phase of such facilities are in progress, and that current studies give promising indications of improved freight car weighing by electronic means.

Report on Assignment 4

Waterfront Terminals

R. H. Peak, Jr. (chairman, subcommittee), M. H. Aldrich, F. E. Austerman, W. S. Broome, G. H. Chabot, S. W. George, L. C. Harman, J. L. Loida, G. L. Roberts, H. T. Roebuck, J. N. Todd, J. C. Warren.

Last year your committee presented as information a report on Ore Piers on the Atlantic Seaboard (Proceedings, Vol. 56, 1955, pages 410 to 412, incl.). This year your committee presents the following report as information:

Rail Facilities for Handling Bananas at Water Terminals

The ship-to-car handling of bananas at ports is a highly specialized operation, which takes place at relatively few locations in the United States. This report outlines the needed facilities, and the reasons therefor, to assist in the design of new facilities, or the remodeling of existing ones.

Trackage used in loading operations may be located at any angle to the water's edge, depending on the land available. Cost of right-of-way and ease of making connections to other tracks are usually the deciding factors in the choice of angle; if these conditions make no difference, a right-angle location will simplify the conveyor system.

The loading tracks are only a small part of the total facility needed to service a banana port.

One of the first considerations must be trackage to hold cars awaiting ships. With cargoes running up to three 250-car ships per week, cars must be accumulated and held in the general terminal area to assure a steady supply when ships are unloading. Since the most common method of ship-to-car handling is by conveyor belts and stevedores,

any delay which causes the belt to stop or idles the men is of serious concern to the fruit company.

Sufficient cars must be cleaned and repaired to handle the expected load upon a ship's arrival. Enough track room must be provided to allow this work to go on with the minimum of delay from switching. Tracks should have at least 25-ft centers between pairs, and either a dolly track or paved roadway should be provided for easy handling of repair materials to cars and removal of rubbish from cars.

Repairs at the cleaning tracks generally consist of minor door, floor and wall repairs to prepare the cars for banana loading. Ordinarily the cars are inspected and any serious defects corrected before placing them on cleaning tracks.

All ice must be removed from bunkers, and all vegetable matter and other trash cleaned out of the cars. Ice may be melted by use of steam or hot water, or may be thrown from bunkers. Ample drainage with frequent inlets must be provided to carry away the water from the melted ice. The trash from the cars may be disposed of by incineration or by dumping. If incineration is used, sufficient burning capacity must be provided to take care of a high precentage of wet, green vegetable matter. After cars are cleaned and repaired they are usually inspected by the fruit company.

After cars are approved, they must be light-weighed. This is generally done by weighmasters from both the railroad and fruit company working together, and must be done with cars at rest and uncoupled on the scale. It is sometimes advantageous to have two scales available so that a breakdown of one will not prevent cars from being ready for the ship.

Hold tracks must be provided adjacent to the dock to hold cars that have been cleaned and weighed. Capacity should be provided for enough cars to take the whole shipload. If any preheating or precooling is done, it is usually handled on or adjacent to these hold tracks.

The number, capacity, and arrangement of tracks on the dock are best arrived at in conference with representatives of the fruit company. The usual method of handling the fruit where any volume is handled is by conveyor from the hold of the ship to the car door, and by manpower to the car interior. The conveyors are usually installed and owned by the fruit company, and may be either belt conveyors having transfer points where corners must be turned, or pallet conveyors which can turn corners. The usual requirement is to have at least one car for each classification of bananas on each track. A double-track lead from the hold tracks to the docks is desirable when two or more engines are to be worked during the ship unloading so that a cut of empties can stand very close to the dock and eliminate delays in spotting empties when loaded cars are pulled.

The unloading tracks should be far enough from the platforms to allow refrigerator doors to be opened. The elevation of the tracks should be such that a man standing on the car floor can conveniently take a stem of bananas from the shoulder of a man standing on the platform.

The railroad usually provides a clerk to check cars and keep records of loading, and shelter and telephone service should be provided for him.

After cars are loaded, checked, and sealed, they must be weighed. If the scale is not close to the dock, cars can be held until a proper-size cut is accumulated for transfer to the yard where the scale is located. The same tracks on which the empties are held can often be used for this purpose. This hold yard should have sufficient capacity to permit efficient switching.

Loaded weights are checked by railroad and fruit company weighmasters working together. Each car must be on the scale at rest and uncoupled at both ends. Trackage should be provided to hold weighed cars waiting to be iced, unless icing facilities can ice cars faster than they can be weighed.

After loads are weighed, the cars must be iced. Icing orders are given by the fruit company and salt is not ordinarily used. It is a customary requirement of the fruit company to have the maximum allowable time between loading and icing a car. This may be as little as 1½ hr.

The iced cars are assembled into trains for departure, or into cuts for transfer to departure yard if it is located away from the icing facilities. Sufficient trackage must be provided to hold iced cars until the proper number have accumulated to move out. It is customary to move each train load as soon as sufficient cars are ready. Classification of cars is not generally done at the originating terminal, as cars often depart before destination is known. The fruit company frequently demands the maximum time limit, usually 3 to 5 hr, between the time the ship is unloaded and the time the last car departs from the terminal. The whole train load will often travel over 400 miles before telegraphic orders give the car destinations and the train can be classified.

When designing a new facility, the various units mentioned above should be located as close together as possible. In particular, the scale and ice facilities should be close to each other and both should be as near the loading tracks as practical. Alternate routes must be provided so that accidents will not stop the ship unloading operations.

Summary of Existing Facilities

Information was received on existing facilities from eight ports served by eight carriers, covering the Atlantic, Gulf, and Pacific seaboards.

The number of ships received ranged from less than 1 per week to 4 per week, with most ports averaging 3 per week. The average ships hold 150 carloads, with some running as high as 260 carloads.

Most roads have their hold tracks at the dock, with others being up to 10 miles from the waterfront. Cleanout tracks are generally found at a separate yard, and have an average total capacity of 130 cars.

Trash disposal is almost evenly divided between dumping and incinerating. Ice is removed almost entirely by throwing from cars, only one road reporting a hot water melting process.

Two of the eight roads have two scales available for weighing; the others, one. Scales are variously located at the cleanout tracks, at the hold tracks, at the docks and at the ice platform, with the majority of roads having them at the cleanout tracks.

One-half of the roads have a two-track lead to the loading tracks. Loading tracks are uniformly arranged for seven or eight-car capacities, with the number of tracks depending on the total capacity. From 32 to 72 cars can be placed at one spotting. Two of the roads operate a car-float arrangement whereby the cars are put on floats and brought to the dock where the ship is unloading; the bananas are handled by conveyor to the edge of the float and thence by hand to the cars.

Other than the car-float operation mentioned above, the unloading is by conveyors, either belt or pallet type, with manpower being used to pick the stems from the conveyor at the car door and stack them in the car. One road reported an occasional small ship unloaded with slings, the fruit being placed on skids and hauled to the car door by tractors.

Most roads use the same scale or scales for loaded weighing as for light weighing.

Icing is generally carried out at an elevated ice platform, with a few roads using trucks equipped with hoisting devices. Very little pre-cooling is done, but most cars are preheated in the winter months. Heaters, when needed, are generally put in at the loading point or at the ice platform.

As might be expected, the more elaborate installations are those serving the greatest volume of traffic.

Report on Assignment 6

Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars

Collaborating with Committees 6 and 16

C. F. Parvin (chairman, subcommittee), W. O. Boessneck, W. S. Broome, J. C. Bussey, J. G. Campbell, S. W. George, J. E. Hoving, A. S. Krefting, B. Laubenfels, H. J. McNalley, B. G. Packard, G. L. Roberts, R. E. Robinson, W. H. Shoemaker, J. N. Todd, G. R. Wurtele.

This is a final report, submitted as information.

Last year your committee presented a first report on this subject and outlined three ways of handling highway semi-trailers on and off flat cars. These ways are:

1. End loading and unloading.
2. Side loading and unloading.
3. Crane loading and unloading.

Studies made during the past year indicate an increase in the number of railroads moving highway semi-trailers on railroad cars. In all known cases, end loading and unloading is still being used. As outlined in the previous report, this method lends itself most readily to expansion to outlying points by the use of either permanent or portable ramps, and such expansions have taken place.

Speed is a prime requisite of this service, and the past year has particularly emphasized the necessity of providing proper facilities for persons fastening or unfastening the semi-trailers on the railroad cars.

In addition to general yard lighting, it is desirable to provide, for night operation, lights at such a level that the undersides of semi-trailers will be lighted when loaded on cars. In lieu of this, outlet receptacles can be provided for portable lights used by gangs securing or unfastening the semi-trailers.

For end loading and unloading, a walkway at railroad carfloor height should be provided along one side of each track to expedite men moving from one car to another. Some railroads are providing such a walkway on the cars.

To expedite the loading of semi-trailers it is desirable in end loading to provide a level space between the top of the ramp and the end of the car. This permits semi-trailers to be more easily and promptly alined with the cars.

In end loading and unloading a ramp grade of not over 8 percent will provide clearance for landing gear or dolly wheels on 35-ft semi-trailers without the use of specially equipped tractors.

Report on Assignment 8 (a)

Location and Design of Car Repair Tracks and Facilities in Relation to Classification Yards

H. C. Forman (chairman, subcommittee), M. H. Aldrich, F. E. Austerman, R. F. Beck, N. C. L. Brown, K. L. Clark, Oscar Fischer, H. J. Gordon, J. E. Griffith, J. E. Hoving, A. S. Krefting, G. L. Lichtenwalner, J. L. Loida, C. J. Morris, H. F. Moy, R. H. Peak, Jr., L. F. Pobl, L. W. Robinson, R. E. Robinson, W. H. Shoemaker, J. N. Todd, P. P. Wagner, Jr., G. R. Wurtele.

This is a final report, submitted as information, with the recommendation that it be submitted for adoption in the Manual next year.

1. Location

Car repair tracks should be located to permit direct movement from one or two classification tracks to the repair tracks. If this arrangement is not practical a connecting track should be provided below the group retarder to which cars can be diverted and then moved directly into the repair tracks.

It is important to have connections which will permit the handling of cars from the repair tracks to the hump or to the receiving yard for rehumping, and also for direct movement to the departure yard. These connections should be arranged so that such movements will not interfere with the work of the hump or pull down engine.

2. Capacity

The capacity of repair tracks depends on the number of cars to be repaired daily. Tracks should be as short as practicable. A minimum of 55 ft should be allowed for each car.

3. Design

Tracks should be connected at both ends. Where possible, they should be spaced at sufficiently wide centers (22 to 26 ft) to accommodate power-operated equipment. Where limited space necessitates, they may be alternately spaced on narrow and wide centers, the narrow spacing to be not less than 18 ft and the wide spacing sufficient to accommodate power-operated equipment.

The working area between tracks should be paved. To permit the use of moving equipment, paved crossings should be located at desired intervals. A jacking block should be constructed along each side of each track on which repairs are to be made.

The following should be considered:

(a) Wheel-handling facilities.
(b) Buildings for offices, storerooms, shops, wash and locker rooms.
(c) Depressed track to permit material to be unloaded at ground level, or a platform at car-floor height.
(d) Air, acetylene and oxygen lines the full length of the repair platforms.
(e) Electric welding facilities.
(f) Material storage between every other track.
(g) Loud speakers and talk-back equipment.
(h) Lighting and drainage.
(i) Shelter for working area.
(j) Load shifter, crane or other device for adjusting or transferring lading.
(k) Facilities for wrecking crane.

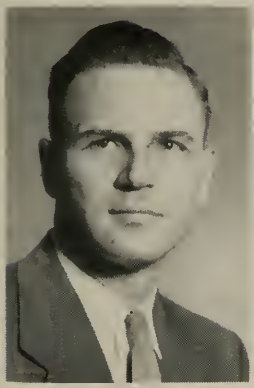
Report on Assignment 8 (b)

Location and Design of Engine Servicing Tracks and Facilities in Relation to Classification Yards

For Subcommittee, See Report on Assignment 8 (a)

Your committee has included in its 1956 program a review of the Manual material on locomotive terminals. In view of this, no report is being made on Assignment 8 (b), and it has been requested that the subject be discontinued.

Report of Committee 25—Waterways and Harbors



A. L. Sams, *Chairman.*

F. B. Manning,
Vice Chairman,

Arthur Anderson
G. H. Beasley
G. W. Becker
C. M. Bowman
C. O. Bryant
H. G. Carter
A. F. Crowder
G. K. Davis
B. M. Dornblatt
W. H. Eckenbrine
N. E. Ekrem
Benjamin Elkind (E)
Oscar Fischer
R. L. Groover
C. J. Henry
B. M. Howard
J. E. Inman
H. F. Kimball
Shu-t'ien Li
G. W. Mahn, Jr.
S. L. Mapes
R. B. Midkiff
J. G. Miller
W. J. O'Connell
H. R. Peterson
C. W. Pitts
R. C. Postels
J. G. Roney
C. M. Seagraves
C. R. Shaw
W. D. Simpson
F. R. Spofford
G. L. Staley
A. B. Stone
J. G. Sutherland
W. R. Swatosh
P. V. Thelander
V. R. Walling
G. A. Wolf

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Current policies, practices and developments dealing with navigation projects, collaborating with AAR Committee on Waterway Projects.

   Oral report to be made at annual meeting

3. Bibliography relating to benefits and costs of inland waterway projects involving navigation.

   Progress report, presented as information ..... page 377

The Committee on Waterways and Harbors,
A. L. Sams, *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 3

Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation

S. T. Li (chairman, subcommittee), C. M. Bowman, A. F. Crowder, W. H. Eckenbrine, N. E. Ekrem, B. M. Howard, H. F. Kimball, G. W. Mahn, Jr., R. B. Midkiff, J. G. Miller, W. J. O'Connell, J. G. Roney, C. M. Seagraves, J. G. Sutherland.

To supplement the bibliographies presented in 1954 and 1955 relating to benefits and costs of inland waterway projects involving navigation, your committee presents the following 36 items as its progress report for 1956, which is submitted as information.

1888

1. Under What Conditions is the Construction of Canals for Bringing Oceangoing Vessels to Inland Port Justified from an Economical Point of View? By E. Leader-Williams; Congres International de Navigation, Frankfort, 1888.

1890

2. On the Cost of Coal Transport and the Mutual Influence of Railways and Canals. By J. Stephens Jeans; Congres International de Navigation, Manchester, 1890.

1892

3. Do Waterways Benefit Railways? By Lewis M. Haupt; Engineering Magazine, New York, April 1892, p. 9.

1893

4. On the Utilization of Water and Rail Routes in Hungary and their Competitive Influence in Reducing Freight Charges. By Alexander Halasz; World Wat. Comm. Cong., Chicago, 1893; Boston, Damrell, in-8° (in No. 8).

1909

5. The Average Speed and Cost of Moving Freight by Railroad by Canal. Engineering News, Vol. 61, No. 13, April 1, 1909, p. 347.

1910

6. The Improvement of Inland Waterways; a Consideration of the Relation between Railways and Waterways and the Improvement of Inland Navigation in the United States; Report of the United States National Waterways Commission. Engineering News, February 3, 1910, Engineering Magazine, March 1910, pp. 918–920.

1911

7. Cost of Rail and Water Transportation. Railway Age Gazette, June 2, 1911.

8. Cost of Transportation on the Erie Canal and by Rail. Bul. 21, Bureau of Ry. Economics; giving an analysis and estimate of cost of transportation on the Erie Canal, seeming to show that it is more expensive to send goods by the canal than by rail. Railway Age Gazette, Nov. 24, 1911. No. 21, p. 1066.

1913–1914

9. The Economics of Canal Transport. Engineering, September 26, 1913, p. 429 (editorial).

10. A Forward Canal Policy: Its Economic Justification. By W. M. Acworth; British Association for the Advancement of Science, Birmingham, 1913, pp. 577–578. London, 1914, J. Murray, in-8° (in No. 8).

1916

11. Canals and the Cost of Carriage Problems. Engineering, February 25, 1916, p. 189; March 3, p. 203 (letter); March 10, p. 239 (letter).

1926

12. Does the New York State Barge Canal Pay? By M. N. Williams, Engineering News-Record, September 9, 1926.

1929

13. Economic Features of the Proposed St. Lawrence Waterway, address by H. G. Moulton, Pres., Brookings Inst., Washington, D. C., before the Traffic Club of Chicago, on March 21, 1929.

1931

14. Railways versus Waterways: An Economic Comparison. By L. D. Cornish; Trans., ASCE, Vol. 95, 1931, pp. 877–897. This is the second part of Paper No. 1779, "Relation Between Rail and Waterway Transportation: A Symposium." 1st part, "Waterway Transportation from the Viewpoint of Operation," by T. Q. Ashburn; 3rd part, "Relation Between Rail and Waterway Transportation," by E. A. Hadley. Entire paper and discussions, pp. 861–950.

1938

15. Economics of the Ohio River Improvement. By C. L. Hall; Trans., ASCE, Vol. 103, 1938, pp. 1527–1578, with discussions.

16. National Aspects of Flood Control, A Symposium. Paper No. 1993, Trans., ASCE, Vol. 103, 1938, with discussions, pp. 551–719. Second part, "Problems in Developing a National Flood-Protection Policy," by Abel Wolman, containing "Financial Aspects"; Third part, "The Economic Aspects of Flood Control," by Nathan B. Jacobs, containing "The Distribution of Costs" and "Benefits of Flood Control"; Fourth part, "Flood Conditions in New England," by W. F. Uhl, containing "Economics of Flood Control."

17. Water Transportation versus Rail Transportation, A Symposium. "The Value of Water Transportation," by Rufus W. Putnam; "The High Cost of Inland Water Transportation," by S. L. Wonson; Trans., ASCE, Vol. 103, 1938, pp. 1279–1333, with discussions.

1939

18. Engineering Economics and Public Works, A Symposium. "Advantages of Orderly Planning," by Frederic H. Fay; "Influence of Public Opinion," by Daniel W. Mean; "Hazards of Uneconomical Construction," by Henry Earle Riggs; "An Appeal to Reason," by William J. Wilgus; and discussions; Trans., ASCE, Vol. 104, 1939, pp. 635–757.

1940

19. Great Lakes Transportation. By M. C. Tyler; Trans., ASCE, Vol. 105, 1940, pp. 167–195; with discussions on costs, and earnings in relation to costs, of the Erie Canal, and its replacement as The New York State Barge Canal, By T. Kennard Thomson, pp. 186–188.

1942

20. Evaluation of Flood Losses and Benefits. By Edgar E. Foster; Trans., ASCE. Vol. 107, 1942, with discussions, pp. 871–924.

1943

21. Allocation of the Tennessee Valley Authority Projects. By Theodore B. Parker; Trans. ASCE, Vol. 108, 1943, pp. 174–216; gives theories of joint-cost allocations, TVA projects.

22. Basic Economic Considerations Affecting Single and Multiple Purpose Projects. By Otis M. Page; Trans., ASCE, Vol. 108, 1943, pp. 353–364, with discussions.

23. Development of Transportation in the United States. By J. E. Teal; Trans. ASCE, Vol. 108, 1943, pp. 1–45; with a section on Transportation Costs and with discussions.

1948

24. Long Range Agriculture Policy (Providing a conservative basis for the benefit-cost analyses in its watershed treatment program), The 1948 Report of the Department of Agriculture on the subject, Department of Agriculture, Washington 25, D. C.

25. Tentative Report of Committee on Cost Allocation for Multiple Purpose Projects, ASCE, 1948.

1950

26. Multiple-Purpose Reservoirs, A Symposium. Trans. ASCE, Vol. 115, 1950, with discussions, pp. 789–908. Sixth part, "Application of General Policies when Used for Irrigation," by Wesley R. Nelson, containing "Allocation of Costs for Altus Project in Southwestern Oklahoma on the North Fork of the Red River," p. 838; "Storage Allocations in Acre-Feet, with Cost Distribution, for Rio Grande Project in New Mexico and Texas," p. 835; "Columbia Basin Project, in Washington State, Cost Allocation and Benefits," pp. 841–843; and "Boulder Canyon Project Adjustment Act Revision of Repayment Plan in Relation to Lake Mead and Related Projects," p. 840; Seventh part, "Coordination with the Electric Utility Industry," by J. B. Thomas, containing "Estimated Costs of United States Multiple-Purpose Dams, Involving Electric Power and Financed by Federal Funds," p. 845. Thirteenth part, "Summary and Review of Principles," by Raymond A. Hill, containing "Economic Factors and Determining Benefits of Multiple-Purpose Reservoirs in Relation to Costs," pp. 890–891; and "Summary", pp. 891–892; discussions, pp. 898, 901.

1951

27. Design Characteristics of Lock Systems in the United States, A Symposium. Trans., ASCE, Vol. 116, 1951, pp. 829–890, containing "Freight rates in relation to building of New York State Barge Canal," p. 866.

1952

28. The Allocation of Costs of Federal Water Resource Development Projects. Report to Committee on Public Works. House Committee Print No. 23, 82nd Congress, 2nd Session, December 1952.

29. Economic Evaluation of Federal Water Resource Development Projects. Report to Committee on Public Works. House Committee Print No. 24, 82nd Congress, 2nd Session, December 1952.

1953

30. Application of Power Revenue from Reclamation Projects. By Charles D. Curran, Legislative Reference Service, Library of Congress, 1953.

31. Some Economic Aspects of Waterway Projects. By Haywood R. Faison; ASCE Proc.—Separates No. 318, October, 1953.

1954

32. National Water Policy. By Thorndike Saville, Proc. ASCE, Vol. 80, Separate No. 442, May 1954, pp. 442–1 to 442–13, containing a section on "Economics."

Year Uncertain

33. Central Valley Project Studies: Problems 8–9, Allocation of Costs; Problems 10–13, Payments by Beneficiaries; Problem 24, Economic Effects. Bureau of Reclamation Publications. Government Printing Office, Washington 25, D. C.

34. Columbia Basin Joint Investigations: Problem 12, Equitable Payments; Problem 13, Allocation of Repayment Charges by Class of Land. Bureau of Reclamation Publications. Government Printing Office, Washington 25, D. C.

35. Cost Allocations. Reclamation Manual XIV. U. S. Department of the Interior, Bureau of Reclamation, Commissioner's Staff Offices, Building 53, Denver Federal Center, Denver 2, Colorado. Attention: Code 841.

36. Project Repayment. Reclamation Manual XV. U. S. Department of the Interior, Bureau of Reclamation, Commissioner's Staff Offices, Building 53, Denver Federal Center, Denver 2, Colorado. Attention: Code 841.

Report of Committee 6—Buildings

O. W. Stephens, *Chairman*

D. E. Perrine,
Vice Chairman,
D. W. Converse, *Secretary,*
C. M. Angel
W. F. Armstrong
S. M. Bielski
C. E. Booth
H. M. Booth
R. R. Cahal
T. S. Carter, Jr.
H. M. Church (E)
C. E. Close
J. S. Cooper
C. E. Defendorf
L. A. Durham, Jr.
V. E. Elshoff
T. J. Engle
R. L. Fletcher
C. S. Graves
A. H. Gustaferro
J. W. Gwyn
W. G. Harding
A. T. Hawk (E)
J. W. Hayes
J. F. Hendrickson
K. E. Hornung
B. J. Johnson
T. M. Kelly
Earl Kimmel
M. L. Koehler
S. E. Kvenberg
L. H. Laffoley
N. C. Le Claire
R. E. Lilliston
I. A. Moore
L. R. Morgan
G. A. Morison
B. M. Murdoch
W. C. Oest
T. V. Pyle
C. L. Robinson
J. T. Rowan
A. B. Ryan
J. B. Schaub
J. J. Schnebelen
J. T. Schoener
H. T. Seal
E. R. Shultz
B. M. Stephens
R. C. Turnbell
S. G. Urban
J. W. Wagner
J. W. Westwood
O. G. Wilbur
T. S. Williams

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress in study, but no report.

2. Specifications for railway buildings.

   No report.

3. Shop facilities for diesel locomotives, collaborating with Electrical Section AAR, Committee 12, Fire Protection and Insurance Section, AAR, Committee 2, and AREA Committee 14.

   Final report, submitted for adoption ..... page 382

4. Wind loading for railway building structures.

   Progress in study, but no report.

5. Sound control for railway buildings.

   Progress in study, but no report.

6. Buildings and structures for classification yards, collaborating with Committee 14.

   Progress in study, but no report.

7. Buildings to house maintenance of way and structures tools and equipment.
   Progress in study, but no report.

8. Fire-retardant paints for railway building interiors.
   Progress in study, but no report.

THE COMMITTEE ON BUILDINGS,
O. W. STEPHENS, *Chairman.*

AREA Bulletin 525, November 1955.

Report on Assignment 3

Shop Facilities for Diesel Locomotives

Collaborating with Electrical Section, AAR, Committee 12, Fire Protection and Insurance Section, AAR, Committee 2, and AREA Committee 14

W. F. Armstrong (chairman, subcommittee), C. E. Booth, J. S. Cooper, T. J. Engle, C. S. Graves, J. W. Hayes, K. E. Hornung, Earl Kimmel, L. H. Laffoley, I. A. Moore, L. R. Morgan, W. C. Oest, T. V. Pyle, J. T. Schoener, H. T. Seal, E. R. Shultz, J. W. Wagner, J. W. Westwood.

Last year your committee presented as information a report on Shop Facilities for Diesel Locomotives (Proceedings, Vol. 56, 1955, pages 429 to 444 incl.), and requested comments and criticisms thereon. This report has been revised and is now submitted with the recommendation that it be adopted and published in the Manual.

SHOP FACILITIES FOR DIESEL LOCOMOTIVES

A. GENERAL

1. General

With dieselization in effect on most railroads throughout the country, the provision of adequate facilities to repair, maintain and overhaul the diesel locomotive units used for road and switching service has become essential.

There are several schools of thought as to what facilities and processes are necessary for the proper repair and maintenance of various diesel units, and while they vary considerably, they are similar in many respects.

2. Building Arrangement

Generally, a diesel repair shop comprises a structure (either new and specifically designed for the purpose, or existing and converted for the purpose) into which diesel units are brought for major overhaul, heavy repairs, inspections, maintenance and servicing. It is preferable that a new shop building be rectangular in shape and be served with through tracks or a combination of through and stub tracks.

The primary consideration in diesel shop planning is that tracks be parallel, and it is recommended that those tracks which are to be assigned for maintenance be through tracks. It is a basic consideration that the diesel locomotive be serviced on a production-line routine, with all sanding, fueling, watering and washing being accomplished adjacent to the lead tracks to the shop building. When a locomotive enters the building for inspection, lubrication and minor repairs, other units follow onto the approach tracks for the outside operations. With maintenance tracks extending through

the building, the locomotive can be taken out of the shop without any interruption to the flow of locomotives following.

The size and arrangement of a diesel shop, the number of tracks, and the type of equipment of the various shops differ on various railroads, depending to some extent on the number of diesel units in service and the policy of the particular railroad with respect to maintenance and repair practices.

The trend in diesel shop design and layout in many instances has been to consolidate the various shop processes in conjunction with the repairing, maintaining and overhauling of diesel locomotives in one large bui'ding. The main portion of the shop is usually divided into two principal sections: the heavy repair section where major overhaul and repairs are made, and the maintenance section where inspections, maintenance and sometimes servicing are done. The heavy repair section usually has the floor at top-of-rail level and is served by an overhead crane. The maintenance section should be provided with pits, depressed floors, elevated platforms and, in some cases, with light-capacity overhead cranes. In addition to these two principal sections, the shop should contain rooms or areas for related repairs, such as machine, electrical, wheel, engine overhaul, steam generator boiler repair, sheet metal, pipe, air brake, truck repair area, filter and small parts cleaning room, small parts reconditioning room, battery shop, plumbing shop, lube oil storage, store room, tool room, office, locker room, lunch room, and toilet facilities.

3. Overnight and Week-End Diesel Housing

In many instances small buildings are constructed at outlying locations to provide overnight and week-end parking or storage. In some cases pits and jacking pads are provided for making miscellaneous light repairs. Suitable heating facilities must be provided in cold climates.

B. EQUIPMENT AND RELATED FACILITIES

1. Equipment

Providing for the equipment and special facilities required in a diesel shop, both as to location and working area, calls for close collaboration with the mechanical department. Some of this equipment, such as drop tables, body-holding devices, overhead cranes, wheel truing machines, fork lift trucks, industrial crane trucks, etc., affects structural and foundation designs. Other equipment or operations may require special rooms or enclosures because of the need for dust and temperature control, such as inspection and repair areas for anti-friction bearings and fuel injectors, the presence of combustible mixtures, such as paint spray and electrical insulation impregnating equipment, or the need to control noise, such as in the area of fixed diesel engine test stands, etc. Provision must also be made throughout the shop for numerous machine tools, fixtures and jigs required by the mechanical department forces.

2. Pits

Inspection pit details vary, but a depth of 4 ft below the top of rail seems to be generally accepted. The pit length should be from 10 to 25 ft greater than the overall length of the locomotives to be serviced. Consideration should be given to the installation of jacking blocks or pads to a point 7 ft 6 in from the center line of track, and such blocks or pads should be provided wherever body jacking is performed. Jacking pads should be provided wherever journal boxes or trucks will be jacked; these pads may be narrower than the 15 ft width recommended for body jacking.

Pit drainage should be provided either by floor drains or sumps located at proper intervals along the length of the pit. The pit walls of reinforced concrete should be either carried to the height of the base of rail or to level of the depressed floor area, with steel columns extended to the height of base of rail for track support. The latter detail is preferred since it affords a positive method of draining the adjacent depressed floor, aids in pit lighting, and provides access into the pit along its entire length. The distance between centers of parallel pits varies from 18 to 26 ft. This distance is established by the desired width of the elevated platforms, except that when a truck release track is introduced between pits, a minimum of approximately 23 ft track centers is required. The rail on inspection pits should be of a heavy section, preferably new.

3. Depressed Floors

The depressed floor along the inspection pits places the mechanic at proper height with respect to the locomotive for inspection and making repairs to trucks, braking systems and other under-body equipment. The elevation of this depressed floor area varies from 2 ft 6 in to 3 ft below the top of rail on the inspection pits. The floor should be well drained and constructed with a surface that is easily cleaned. The recommended slope is $\frac{1}{8}$ in per ft.

4. Elevated Platforms

Elevated platforms in the areas between adjacent maintenance tracks, as well as along the outer sides of these tracks, are desirable in the diesel locomotive maintenance shop. The height of the platforms with respect to the top of rail is most generally 4 ft 8 in to 4 ft 11 in, with some constructed at 5 ft 6 in. The distance from edge of platform to center line of track must be held to the minimum of 5 ft 6 in, or as otherwise necessary for the proper clearance of the equipment. Platforms should be constructed of non-combustible material, usually consisting of steel columns and beams, or of reinforced concrete.

Narrower platforms, approaching the minimum widths that will permit two material-handling trucks or transporters to pass, should be given consideration since they overcome the objection that wider platforms allow materials and parts to be left on them when they should be moved to repair areas, stores or scrap for better housekeeping. Where repair areas are not located on or under platforms, the track spacing might be reduced to 18 ft between track centers, except where columns make it necessary to increase platform widths.

Platforms should be provided with removable handrails along all edges, consisting of either pipe or a combination of pipe supports with chains between them. Access to the platforms from the normal top-of-rail level and depressed level floors should be provided by means of stairs and ramps at the ends and at intermediate points.

Access from one platform to another is most desirable and can be accomplished by means of bridges. Such bridges must be removable and can be a simple form of gangplank set into place and removed with a lightweight, motorized monorail hoist, or an electrically operated elevator-type bridge having rails in its floor, which can be depressed into the inspection pit when necessary to move locomotives past the line of the platform bridge crossing. This latter type of bridge is the best means of inter-platform communication but its control should be interlocked with the door-operating mechanism to avoid the possibility of accidents.

High-level platforms, approximately 15 ft 3 in above the top of rail, are sometimes used. This platform is particularly desirable if locomotives require removal of cylinder

heads from a roof hatch. The high-level platform is usually the same width as the lower level platform, with stairs located at convenient points between the levels.

Portable platforms are used in some instances where fixed elevated platforms and depressed floors are not desired.

5. Truck Replacement

Jacks, transfer pits and drop tables are used for changing out wheels and trucks.

Drop tables with spacer posts, using either electric or hydraulic hoisting and racking motive power, are the most generally accepted equipment for the truck-changing operation. Requirements as to capacity of the drop table depend upon the locomotives to be serviced. Most generally, those of 100-ton capacity are used. Table tops 18 ft in length are required for 4-wheel trucks and 23 ft 6 in for 6-wheel trucks. In some instances tables 26 ft long have been installed.

Numerous railroads are using drop tables approximately 6 ft 6 in long for exchanging individual wheel pairs, with or without traction motors. Some of these are installed separately and others in combination with drop tables or transfer tables of sufficient length to permit handling complete trucks.

Truck release tracks may be provided and arranged between each pair of tracks; i.e., in a 4-track shop, release tracks should be provided between tracks 1 and 2 and between tracks 3 and 4. With such an arrangement, a drop table pit depth of 8 to 10 ft will be sufficient. This arrangement will avoid the necessity of lowering the table, its top and truck below another table to reach the release track, which would require a pit depth of approximately 16 to 18 ft, thus increasing the cost of installation. On the other hand, the deep drop pit may cost less than the additional building width required for more than one release track, and shop operations may be more economical if the space between working tracks is clear instead of filled with wheels and trucks. The cost of truck and wheel storage in tunnels should be compared with the cost of additional trackage, if sufficient area is available for that storage at ground level.

Necessary for use with the drop table is the body support, either a box girder above the floor, or a box girder below the floor with only a post-type support above the floor. With drop tables more than 23 ft long, the body support rests should have longitudinal adjustment, as fixed-center rests will result in placing the second truck of certain locomotives on the table top.

The investment in the installation of drop-table hoisting equipment and body supports can be justified at those points where major diesel locomotive maintenance and repair work are done on enough units to effect savings in labor as well as in the time of returning locomotives to service. At those terminal points where locomotives are only serviced and turned, there may be occasion for truck removal only as an emergency measure. At such locations jacks, crane or a side release table may be provided.

6. Truck Repairs and Overhaul

Repairs and overhaul to trucks are made in an area somewhat removed from the area where work is done on the locomotive. Such an area should be provided with a truck washing platform for cleaning prior to the overhaul. Facilities for steam cleaning and the use of detergents should be provided. Wheel truing installations for turning down locomotive wheels without their removal from trucks are being used successfully in many shops. Lathe units are also used to mill wheels without removing the trucks from the locomotives.

7. Electrical Shop

Shops may be desired for the repair and overhaul of electrical equipment. Provision must be made for adequate floor area, machine foundations, power wiring, lighting, heating, ventilating, fire protection and hoisting equipment.

8. Engine-Overhaul Shop

The engine-overhaul shop is primarily for dismantling and reassembling engines, which operations are accomplished most satisfactorily in an area separated from the main shop. The room should adjoin an area served by an overhead crane from which an engine can be set on a "dolly" and wheeled into the engine shop. As the engine work requires the handling of heavy parts, hoisting equipment of adequate capacity is required. A small pit is desirable on each side of the engine assembling track, 2 ft 8 in wide, 2 ft 6 in to 2 ft 9 in deep, and 35 ft long between stairs at each end.

9. Small-Parts Reconditioning Shop

Space may be desired for a small-parts reconditioning shop. Provision must be made for adequate floor area, machine foundations, power wiring, lighting, heating, ventilating, fire protection and hoisting equipment.

10. Filter and Parts-Cleaning Room

It is important that this room, or building, be isolated from other areas, since the steam and moisture from the cleaning tanks is most injurious to finely machined engine and electrical parts exposed in overhaul operations. Ventilating hoods should be placed over the cleaning vats. Walls or ceiling areas exposed to cold temperatures should be insulated to prevent condensation from moisture-laden air. Walls, ceiling and structural steel may require special treatment to withstand the corrosive effect of vapors. Overhead cranes or hoists should be provided for transferring filters and parts through the various vats, drying ovens, oilers, etc. Attention should be given to providing adequate floor and equipment drainage; that is, the waste should be carried through an oil separator before discharging into the sewer system. A caustic tank should be located outside of the building to permit the removal of grease and paint from the large parts which cannot be accommodated in the parts-cleaning shop.

11. Store Room

In order that repair parts may be readily available for maintenance, a store room for diesel parts should be established as an integral part of the diesel shop. As the nature of store stock includes finely machined and finished parts, the construction should be such as to provide a dry, dust-tight, well lighted, ventilated and temperature-controlled room. The store room should be located at elevated platform level to suit incoming deliveries at car-floor height and issues to platforms where many replacements are made. The purchasing and stores department should be consulted as to direct area requirements.

12. Office

An office area for the use of the diesel shop supervisor and his clerical staff should be located adjacent to the main shop area for proper supervision and the maintaining of servicing records, preferably on the same level as the working platforms.

13. Locker and Toilet Facilities

Adequate locker, lunch, toilet and washing facilities should be provided to meet requirements, and be so located as to be as accessible as possible. Individual state and

local codes covering sanitary facilities should govern; however, the suggested approximate minimum requirements for various fixtures are:

One individual water closet for every 20 employees per shift.
One individual urinal for every 40 employees per shift.
One lavatory for every 10 employees per shift.
One shower for every 20 employees per shift.
Drinking fountains as required.

Wash basins and urinals should be installed at convenient locations in the shop and repair areas.

C. SERVICE FACILITIES

1. Lubricating Oil Supply

Proper lubricating oil facilities are important at a diesel shop, as they make possible rapid oil changing and normal servicing with minimum of expense in the handling of oil. Modern oil-handling equipment contributes to keeping the premises clean and minimizes the fire hazards which usually result from old fashioned methods of bulk handling of oils. Provision for dispensing lubricating oil should also be made in a heavy repair shop for refilling the crank cases of locomotives following repair.

It is customary to keep each refiner's oil separate. This necessitates separate storage, pumping and dispensing facilities for as many different kinds of oil as are to be used. Storage tanks of such capacity as to permit purchases in tank-car lots are recommended for the larger shops. Pumps should be of suitable capacity and should be valved and piped to permit their use for unloading tank cars and for distribution from the storage tank to the dispensing stations.

Oil dispensing stations located on the elevated platforms consist of separate hose reels for each kind of lubricating oil, with 50 ft of hose. Dispensing stations should be located on approximately 60-ft centers and hoses provided with spring-loaded nozzles for quick-action control of oil flow. Meters may be provided to measure the quantity of oil used in servicing locomotives. Such a dispensing system is of value in adding small quantities of oil or in making complete oil changes. In some instances lubricating lines require heating, and pumps should be controlled from the unloading and dispensing stations.

2. Lubricating Oil Drainage

Oil drainage systems usually consist of a tank placed at a level lower than the inspection pits, with connecting piping from the pits for gravity flow into the tank. Connections should be provided at intervals throughout the length of the pit for making hose connections with the engine drains. The dirty oil is pumped from the gravity storage tank into tank cars and returned to the reclamation plant.

In many instances forced oil drainage systems are preferred and are installed with pumps of suitable capacity; thus storage tanks may be kept above floor level.

Portable drain and lubricating oil tanks on wagons of approximately 250-gal capacity should be provided for servicing locomotives in the repair areas not provided with the lubricating oil dispensing and drain oil systems.

3. Water Supply Systems

Treated steam-generator boiler water, radiator water and raw water outlets are usually provided at convenient intervals along the maintenance tracks. These outlets are generally placed on the underside of the elevated platform.

Treated water for diesel engine radiators may be heated by steam in a heat exchanger and pumped through a closed system to the outlets.

The recommendations of the Committee on Water, Oil and Sanitation Services, as presented in Chapter 13, should be used as reference in this connection.

4. Compressed Air

Compressed air outlets are usually provided at convenient intervals along the underside of the elevated platforms.

5. Steam

High-pressure steam outlets are usually provided at convenient intervals along the underside of the elevated platforms.

6. Steam Generator Blow-Down and Testing

Outlets in the pit may be provided to connect with the train-line steam hose. The steam passes from an outlet to a blow-down basin. The basin should be vented and provided with a drain.

D. ARCHITECTURAL AND STRUCTURAL DETAILS

1. Floors

Concrete floors throughout the shop are recommended. Anti-slip materials are recommended on inclines and steps. Special precautions should be taken in connection with the preparation of concrete floors in battery shops or other acidic areas, such as steam generator washout locations, and fueling and oiling areas, to prevent deterioration of these floors.

2. Walls

Walls should be of brick, reinforced concrete, insulated metal panels, cement-asbestos, galvanized steel, aluminum, or concrete block. They should meet all fire protection requirements.

3. Roof

Steel purlins with fireproof deck should be used where possible. Consideration must be given to protection of the underside of old wood roof decks with fire-retardant paint or other suitable coverings.

4. Doors

Diesel locomotive entrance doors should be at least 14 ft wide and 17 ft high, or as required by state clearance regulations. Generally they are motor-operated overhead steel rolling doors. Doors should be of electro-galvanized steel and should be painted periodically. Provision for hand operation should be made in case of power failure or breakdown.

Fire doors on any wall opening should be so built as to warrant classification as a fire wall.

5. Windows

Windows should be of steel or aluminum, with sash operators. Glass blocks should be either light-direction or light-diffusion types.

6. Painting

The diesel locomotive shop permits use of an entirely different color scheme for interior painting than would be considered practical in roundhouses and shops for steam power. For the greatest amount of light reflection, the painting may be of pastel shades consistant with the theory of color dynamics. Hand rails, stairs, crane hooks and obstructions should be painted bright colors which will be "eye arresting" to the safety hazards which such objects may present. Piping should be painted distinct, identifying colors to aid in preventing errors in locomotive or building maintenance operations.

E. HEATING AND VENTILATING

1. Types and Design

The problems involved in heating and ventilating diesel shops are those of removing the exhaust gases from locomotives on test and tune-up, replacing combustion air consumed by the engines with tempered fresh air, and the replacement of heat loss through the building.

At outlying terminals, where one particular type of diesel locomotive may be housed and maintained, a simple type of telescopic stack fitted with a rain hood or syphon ventilator may be provided for each exhaust port of the locomotive. When engines are to be run while in the house, the stacks are lowered over the exhaust ports, the exhaust having sufficient velocity to expel itself. Unit heaters, generally used for heating such buildings, can be provided with a duct having an outside air intake and adjustable damper for either introducing 100 percent fresh air or 100 percent recirculated air.

The problem becomes a challenge in terminal shops where the locomotives to be maintained and repaired are of many types and different manufacture. The individual exhaust stack is no longer practical, and the problem is one of providing a mechanical ventilating system.

If an overhead crane does not operate in the maintenance area in which most engine testing is done, it is possible to provide hoods on the center line of each track and, by means of power exhaust units, collect the gases close to the source and expel them from the building. In some instances continuous exhaust ducts are fitted over each maintenance service track, running the full length of the pits, with motor-operated exhaust fans installed at 30 to 40-ft centers exhausting through the roof deck. These fans may be automatically controlled by thermostats located in the ducts which cut in and out at predetermined temperature settings. A manual-start, one-minute arrangement may also be incorporated. Hoods are generally constructed of asbestos-cement board or sheet metal on a steel frame. This method has the advantage that at least a portion of the locomotive exhaust gases are removed from the building while they are still in concentrated form; i.e., before they fully disperse into the total volume of air in the shop, and fewer air changes are necessary to keep concentration requirements within recognized limits.

Another method of providing ventilation in maintenance areas, as well as in high crane bay areas, is to install power exhaust units at proper locations throughout the roof area. Roof areas should be divided into cells by facing one side of roof trusses with asbestos-cement board or sheet metal, the cells confining the gas to an area served by individual exhaust units, permitting operation of individual ventilators as required.

In either of the above-mentioned methods enough cubic feet per minute must be exhausted to remove the exhaust gases before they cool and settle of their own weight.

As a result of tests conducted by the U. S. Department of the Interior, Bureau of Mines, in the Cascade Tunnel of the Great Northern Railway during October 1944,

valuable data were obtained for the calculation of a diesel shop ventilating system. The diesel locomotive used in the test was an EMD 5400-hp, 4-unit freight locomotive, and gas samples of engine exhausts were taken at idling speed (275 rpm), ¾ speed (650 rpm), and full engine speed (800 rpm). The test developed that 0.375 lb of fuel is consumed per hp-hr and 434.4 cu ft of exhaust gas is produced for each pound of fuel consumed. The scavenging and intake air supplied through blowers was 4.27 cfm per hp. Inasmuch as horsepower will vary as the speed, the base horsepower at idling speed (275 rpm) will be 0.344 of full speed (800 rpm) horsepower. Samples of exhaust gases taken at the exhaust outlets developed the following:

Engine Operation	*Composition of Samples (Percent of Volume)*					
	Carbon Dioxide	*Oxygen*	*Carbon Monox.*	*Hydro-Carbons*	*Nitrogen*	*Oxide of Nitrogen (Parts per Million)*
Full throttle (800 rpm)	6.52	11.93	0.20	0.06	81.29	1117
¾ (650 rpm)	4.52	14.83	0.03	0.00	80.62	936
Idling (275 rpm)	0.68	19.98	0.01	0.00	79.33	145

The following is a typical calculation to determine the building exhaust requirements, similar calculations to be carried out for the maximum number of locomotives which will run in the shop at one time. In idling one 3-unit, 6000-hp diesel, the total engine exhaust gases would be

$$\frac{6000 \times 0.375 \times 0.344 \times 434.4}{60} \text{ equals } 5604 \text{ cfm}$$

As the ventilation system must satisfy either code regulations or accepted good practice, consider a typical code requirement which allows a 10 percent exhaust gas concentration or 10 parts per million of oxides of nitrogen concentration. To satisfy the limit of 10 percent exhaust gas concentration, it would require dilution with fresh air of 10 times the exhaust volume, or approximately 56,000 cfm. The governing factor is in reducing the oxides of nitrogen concentration to less than 10 parts per million. From previous exhaust gas analysis the existence of 145 parts of oxides of nitrogen at idling speed was found, requiring 15 times the volume of fresh air, or approximately 84,000 cfm exhaust.

It will, of course, be necessary to supply heated outside air to supply combustion air, as well as to replace the air exhausted (determined above). The combustion air requirements for the 6000-hp diesel would be as follows:

$$4.27 \times 0.344 \times 6000 \text{ equals } 8808 \text{ cfm}$$

The 84,000 cfm exhaust plus the 8808 cfm air consumed in combustion requires the minimum of 92,000 cfm supply air.

The fresh air intake units should be as widely separate from the exhaust units as possible to avoid "short circuiting" of fresh air to exhaust units. The heated fresh air supply should be introduced by large units specifically designed for this purpose, and air should be introduced at the lowest point practicable or, if elevated, the intake air should be deflected by fins downward to aid in the movement of air upward and outward through the roof ventilators. The air supply should be widely distributed at the lowest possible velocity to avoid discomfort to mechanics working on the lower floor and plat-

form levels. Inspection pit heating for employee comfort and for defrosting the undersides of the locomotives in an important consideration.

In addition to fresh air introduced into the building to replace that consumed by engine combustion and exhaust units, space heating units to offset natural building heat losses must be installed to heat the building when the exhaust ventilation system need not be operated. This may be a composite system which might include radiant heating panels in floors, forced warm air supplied to service pits, fin-type coils along exterior walls, or unit heaters. It is advisable to install supplemental unit heaters over large door openings, which may be operated when doors are opened in cold weather.

F. ELECTRICAL

1. Lighting and Electrical Outlets

For servicing and repair shops functioning over a 24-hr period an adequate artificial lighting system is a requirement of utmost importance. For foot-candle intensities, see the recommendations of the AAR Electrical Section.

Recessed waterproof fixtures along the walls of the pits have proved successful in providing illumination for inspection and repair under the locomotive.

Illumination of the trucks of locomotives and areas under the platforms can be done effectively with angle-type fluorescent fixtures, with glass covers to protect against dirt and moisture.

General illumination over the overhaul and maintenance areas can be accomplished by high bay incandescent or mercury vapor color-corrected lamps, or a combination of both.

Suitable electric outlets of proper phase should be located throughout the inspection pits, and maintenance and repair areas for extension cords to power tools, steam generator washout machine, vacuum cleaners, welding machines, battery chargers and other heavy-duty tools.

Circuit breakers should be used in lieu of conventional fuses.

G. OVERHEAD CRANES

1. General

As the nature of operations in repair, overhaul and maintenance areas requires handling various locomotive components, the overhead crane is an essential facility; and the following suggested capacities and lift heights should be given consideration.

2. Above Engine-Stripping, Overhaul and Assembly Areas

If complete engines, less main and auxiliary generators, are to be lifted:

20 ton—12-ft lift above floor.

If main frames or blocks are to be separated and lifted from bases or oil pans without stripping the power assemblies (heads, pistons and rods, liners) and other items therefrom:

20 ton—12-ft lift above floor.

If main frames or blocks are to be separated and lifted from base or oil pan after having been stripped:

7½ ton—12-ft lift above floor.

If crankshafts and other smaller engine components are to be lifted, on the basis that the engine and main frames or blocks will be handled under cranes in an adjoining bay by rolling them to and from on dollies:

2½ ton—12-ft lift above floor.

To permit lifting all engine components, except crankshafts, main frames or blocks and bases, or oil pans on the basis that such will be handled under a larger crane in an adjoining bay by rolling them to and from larger cranes on dollies:

1 ton—12-ft lift above floor.

3. Above Maintenance Tracks, Including Depressed Floor and Pit Tracks with Elevated Platforms

2-ton—20-ft lift above top of rail.

4. Above Maintenance and Repair Tracks in a Small Shop Handling Both Maintenance and Repairs

If axle-mounted wheels and traction motors will be handled separately, in addition to other parts:

5 ton—24-ft lift above top of rail to permit lifting larger components out of units.

If an assembly consisting of traction motor wheels, axles and roller-bearing journal boxes will be handled as a unit:

10 ton—24-ft lift above top of rail to permit lifting main generators and other large components out of unit.

If locomotive body will be jacked and truck work handled by lifting one end of truck only:

20 ton—24-ft lift above top of rail.

*If diesel engine is to be lifted out of units:

30 ton—30-ft lift above top of rail.

*If complete trucks are to be lifted:

40 ton—30-ft lift above top of rail, assuming the same crane will also be used for lifting diesel engine out of units.

*If one end of body is to be lifted without trucks attached:

60 ton—30-ft lift above top of rail, assuming the same crane will also be used for lifting diesel engine out of units.

*If one end of locomotive is to be lifted with the trucks suspended therefrom:

100 ton—30-ft lift above top of rail; or 36-ft lift above top of rail if locomotives are to be lifted over each other using two 100-ton cranes, one at each end of the unit.

*If complete locomotives are to be lifted with trucks suspended therefrom:

200 ton (one crane with two 100-ton trolleys)—36-ft lift above top of rail, if locomotives are to be lifted over each other.

* These crane capacities and lifts are also suitable for repair or overhaul shops whether or not associated with maintenance and light repair facilities.

Many of the above crane capacities and lift heights can be reduced if careful check is made of the locomotives to be handled, since the figures shown are intended to cover the largest and heaviest locomotives now in service.

If allowance is to be made for future types of motive power, including the gas turbine-electric, etc., certain of the above capacities should be increased considerably. As the most costly units are the larger cranes, consideration should be given to purchasing the larger cranes with 50 percent greater capacities than indicated above to allow for future contingencies, since the price difference usually is proportionally less than the increase in capacity.

H. FIRE PROTECTION

Diesel shops should be built of fire-resistant materials throughout. Where economy in the initial investment makes necessary the use of existing frame buildings, these should be provided with reinforced concrete floors and platforms, and the superstructure should be coated with fire-retardant paint.

Ventilating hoods in servicing areas where most engine testing is done, as referred to in Sec. E. Heating and Ventilating, also serve to preclude the deposit of residue from the exhaust fumes of diesels on flammable roof construction, thus reducing a possible fire hazard. These hoods should be of fire-resistant construction and, where possible, equipped with steam jets to facilitate cleaning. The use of hoods will minimize the necessity of fire-resistant painting on the underside of the roof deck.

The introduction of the general-purpose shop with one large building introduces additional fire hazards, which should be adequately guarded against from the fire prevention standpoint. Good practice indicates that serious hazards should be safeguarded by the provision of separate cut-off enclosures to prevent any serious spread of fire, and enclosures should preferably be provided for lube oil storage tanks and pumping equipment, boiler room, battery repair and charging rooms, locker and wash rooms, filter cleaning room, and paint storage room, as well as any other areas containing high fuel values or hazardous processes. In some cases it is desirable to provide curtain walls to divide large ceiling areas into cells as a means of controlling and confining fire, and also to provide separate enclosures for engine parts repair and injector servicing to make the rooms free from soot and smoke.

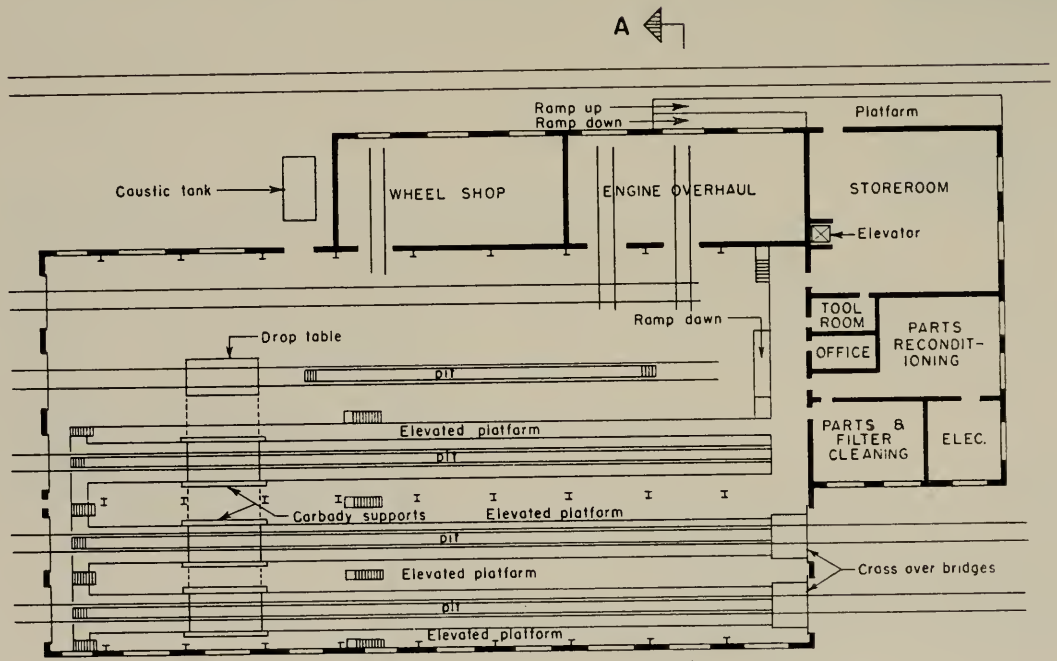
Under certain conditions there is a possibility that some types of fire extinguishing devices, such as the automatic carbon dioxide flooding systems may, when used, operate to reduce the oxygen content of the air to a dangerous level. Some types of extinguishers, when used, may generate toxic fumes. Both of these circumstances warrant attention to insure the personal safety of employees.

It is desirable to consider the use of automatic fire detection devices, particularly at points where there may be times when no employee is in the vicinity for long periods of time, such as week ends and holidays.

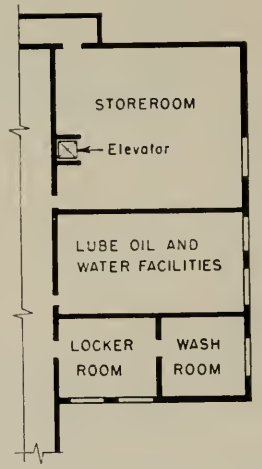
Notwithstanding the provision of enclosures for areas of serious hazards, there remains the large area with its numerous general hazards, such as oxyacetylene welding, electric arc welding, spray painting, electrical equipment, varnishing, insulation and cleaning, all of which should be adequately protected by suitable extinguishers supplemented by fire hose and combination nozzles where indicated by the circumstances. In some cases portable, 6-ft or longer, pipe-mounted fog nozzles have proved very satisfactory.

Consideration should be given to the proper collection and venting of fumes and vapors from hazardous areas or operations as an alternative to providing separate en-

closures for these areas and processes, since enclosures within a shop facility will impede normal shop operations and work flows, as well as the delivery of materials, parts, etc. Velocities for exhaust should comply with the requirements of state and local codes to prevent the spread of hazardous fumes and vapors. The collection of fumes should be made by means of high-velocity type hoods, the fumes to be exhausted directly outside the building in accordance with code requirements. Approximate velocities should be 300 to 500 ft per min.

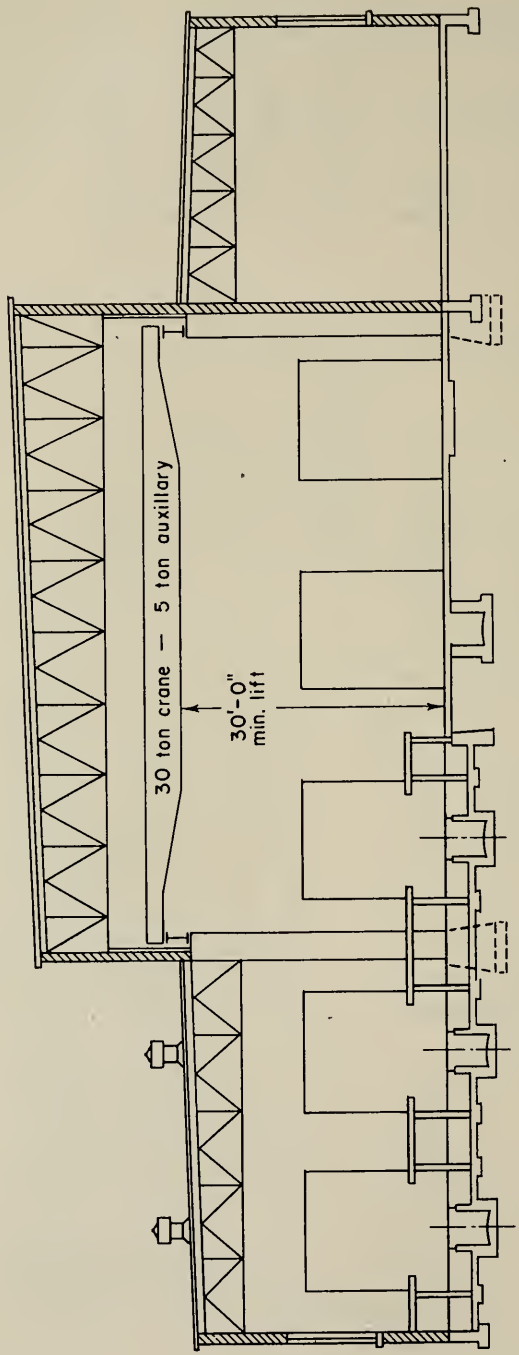


FLOOR PLAN



PLAN OF LOWER LEVEL

TYPICAL HEAVY AND RUNNING REPAIR SHOP FOR DIESEL LOCOMOTIVES



SECTION A-A

Report of Committee 22—Economics of Railway Labor

D. E. Rudisill, *Chairman.*

L. A. Loggins,
Vice-Chairman,
L. C. Gilbert, *Secretary,*
Lem Adams (E)
A. D. Alderson
M. B. Allen
H. C. Archibald*
J. F. Beaver
B. V. Bodie
W. H. Brameld (E)
E. J. Brown
R. H. Carpenter
G. E. Chambers
A. B. Chaney
P. A. Cosgrove
C. G. Davis
M. H. Dick
W. W. Edwards
J. E. Eisemann
H. J. Fast
J. L. Fergus
W. H. Freeman
R. J. Gammie
C. G. Grove
W. H. Hamilton
K. H. Hanger
E. B. Harris
G. L. Harris
W. W. Hay
W. H. Hoar
G. W. Hunt
T. B. Hutcheson
Claude Johnston
H. W. Kellogg
G. A. Kellow
N. M. Kelly
W. I. Kino
H. E. Kirby
Roy Lumpkin
J. S. McBride (E)
J. F. McCook
E. H. McIlheran
W. H. Miesse
H. C. Minteer
J. P. Morrissey
G. M. O'Rourke
R. W. Pember
J. A. Pollard
B. C. Pratt
R. R. Pregnall
L. F. Racine
W. R. Rees
M. S. Reid
L. H. Rose
R. R. Smith
J. S. Snyder
F. R. Spofford
P. V. Thelander
W. H. Vance (E)
H. J. Weccheider
H. M. Williamson
H. E. Wilson
F. R. Woolford
C. R. Wright
Committee

(E) Member Emeritus.
* Died August 6, 1955.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work.

   Progress report, presented as information ..... page 398

3. Comparative economy of routine track maintenance with limited size forces, and cycle, out-of-face track maintenance with fully mechanized forces.

   Final report, presented as information ..... page 417

5. Labor economy of renewing ties by use of proper equipment, methods and organization.

   Final report, presented as information ..... page 423

6. Labor economies of various mechanical methods of tamping and equalizing ballast, including the double shifting of machines.

   No report.

7. Comparative economy of handling maintenance of way gangs in trucks versus motor cars, including economical length of haul, collaborating with Purchases and Stores Division, AAR.

Final report, presented as information ..... page 424

8. Economic size of maintenance force using on or off-track tampers and renewing an average of 100 ties per mile.

Final report, presented as information ..... page 430

The Committee on Economics of Railway Labor,
D. E. Rudisill, *Chairman*.

AREA Bulletin 526, December 1955.

Report on Assignment 2

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

J. E. Eisemann (chairman, subcommittee), B. V. Bodie, E. J. Brown, W. W. Edwards, H. J. Fast, R. J. Gammie, C. G. Grove, W. H. Hamilton, E. B. Harris, G. L. Harris, W. W. Hay, T. B. Hutcheson, Claude Johnston, H. W. Kellogg, G. A. Kellow, N. M. Kelly, H. E. Kirby, E. H. McIlheran, W. H. Miesse, H. C. Minteer, G. M. O'Rourke, L. F. Racine, W. R. Rees, L. H. Rose, J. S. Snyder, F. R. Spofford, P. V. Thelander, H. E. Wilson, F. R. Woolford.

Submitted as information, this is the fourteenth report of a series on this subject, which has been reassigned annually since 1935. The current study covers a reorganized and comprehensive system of track and roadway maintenance on the Southern Railway, previous studies having dealt with various maintenance operations on the Lehigh Valley; Norfolk & Western; St. Louis–Southwestern; Great Northern; Illinois Central; Denver & Rio Grande Western; Delaware & Hudson; Delaware, Lackawanna & Western; Pennsylvania; Elgin, Joliet & Eastern; St. Louis–San Francisco; Atchison, Topeka & Santa Fe; and Chesapeake and Ohio railroads.

Data for the current study were obtained by the committee during an inspection, on July 13, of the operation of one of the completely mechanized, combined tie renewal-surfacing gangs on the Southern Railway. On the same day the committee also inspected the Southern's central work equipment shop at Charlotte, N. C., where it observed several new pieces of equipment being developed by this company.

In carrying out its mchanized tie renewal–surfacing operation, the Southern uses the machines listed in the accompanying tabulation, which includes their stated assignment, and the labor force required to operate them. The duty of the organization is to renew all ties requiring replacement, based on a 5-year cycle, and to perform the minimum surfacing job behind the tie renewal work. The minimum surfacing job amounted to a maximum raise of 1½ in and included the pulling of sags up to grade.

In the following tabulation, the equipment is listed in order of use.

Machinery	*Personnel*	*Description of Work*
	1 Flagman (laborer)	
1 Ballast equalizer	1 Machine operator	In the morning, a special attachment on the equalizer digs out ends of ties to be renewed ahead of the gang operation. In the evening, it moves to the rear of gang and dresses track.
1 Hydraulic spike puller	1 Helper	Pulls spikes from ties to be renewed and removes rail anchors.
2 Tie removers–inserters	2 Machine operators 4 Laborers	These machines remove the old ties and install new ties. Old ties are loaded on special tie carts towed by the remover–inserter machine, where they are banded for easy loading. Bundles are unloaded along side of track.
	3 Laborers	Drive down high spikes and set spikes in new ties and regage where necessary.
1 Multiple spiker	1 Helper	This machine nips the ties and drives the spikes with air hammers at the same time.
1 Ballast scarifier and equalizer	1 Machine operator	Equalizes the ballast for the tamping machines and has special equipment for routing up blacktop crossings.
	1 Laborer	Digs jack holes.
	2 Jackmen	Set jacks and raise track.
	1 Level board man (asst. foreman)	Handles level board in track raising operation.
	1 Foreman	Spotting track for raising operation.
1 Jack carrier	----------	18 jacks were used on each rail. Jack carrier automatically carries jacks between tamping machine and men setting jacks. Total of thirty-six 5-in.-raise jacks in use.
	2 Laborers	Remove jacks ahead of tamper.
2, 600-cfm, 16-tool tamping machines	2 Machine operators	Each machine tamps alternate ties.
1 Power track liner	1 Machine operator 1 Liner (asst. foreman) 1 Laborer	Asst. foreman liner and machine operator line the track with lining scope and targets. The laborer applies rail anchors and assists in gassing equipment, also drives fuel truck. Works 10 hr per day.
1 Power track broom	----------	Dressing track and sweeping off ties with broom.
	1 Flagman	Flagging trains.
	27 Total	

Personnel used:
1 extra gang foreman
2 assistant extra gang foremen
7 machine operators
2 machine operator helpers
13 track laborers
*2 flagmen
1 equipment maintainer
1 assistant track supervisor

*Optional use, as movements of trains in and out of area can be controlled by radio contact with the engineer.

The particular operation inspected by the committee was being performed on the Charlotte Division of the Eastern Lines of the Southern, located between MP 358 and MP 359, approximately 4 miles south of Concord, N. C., and between Concord and Charlotte. The track being surfaced is one of two main tracks at this location. The committee was advised that the traffic over this territory amounted to approximately 12

million tons per year, or approximately 6 million tons of traffic on each of the two main tracks. The rail at this location is 132–25–CC–Tennessee–1955, and had been laid earlier in the year. There are 12 rail anchors applied per rail, 8 holding in one direction and 4 boxed to prevent rail movement in the opposite direction. There are twenty-one 8-ft 6-in creosoted ties per panel, plated with 7¾-in by 13-in double-shouldered 8-hole tie plates, punched on 3½-in centers for line spikes and 4½-in centers for hold-down spikes. Six-hole, head-contact angle bars, without depending flange, with a punching of 6–6–7–6–6, are used at the joints. Insulated joints are 6-hole, armored type, and all the rail is head bonded. The ballast is ¾ to 1½-in crushed granite obtained from a quarry located at Blair, N. C.

On the inspected section of track a mechanical ballast cleaner had been operated slightly more than a month in advance of the rail laying operation. This amounted to preparatory work for the surfacing performed at the time of the committee's inspection. Other, and more immediate, preparations for this operation would include the precise unloading of ties at the exact points where they would be needed. At the time of the inspection, the organization was completing the surfacing work within the limits of the newly laid rail. The total distance the gang had covered was approximately 24½ miles, between MP 334 and MP 358½, and the work was accomplished in 48 working days. In other words, the rate of progress for the entire gang amounted to slightly over ½ mile per day, on the average, but this included all switch and road crossing work within the limits of the rail relay. As opposed to this progress figure, the Southern people stated that the gang could, in open track, complete this work at the rate of 800 track feet per hour of on-track time and could renew up to a total of 400 ties per day. Ordinarily, track occupancy time amounted to about 4 hr 45 min each day.

At the present time, the Eastern Lines of the Southern are equipped with 7 sets of the above enumerated equipment. The Eastern Lines include 3200 miles of main track and 1200 miles of yard and side tracks, along with 7000 turnouts. It is considered that one set of this equipment will satisfy the tie renewal and surfacing requirements of 450 miles of main track, and it was stated that, over a long term, including repair time and other down tie, a set of equipment will cover 100 main-track miles per year. It should be here noted that this equipment is used on a road where year-around work can be performed on the majority of the system. Detailed unit cost and system organization figures could not be obtained and are, therefore, not a part of this report.

The work inspected was on the Charlotte Division of the Eastern Lines, but advice concerning the plans for the remainder of the system was requested and received. The Central Lines have 5 sets of this equipment, which constitute the full assignment and will provide the necessary machines to perform the above described cycle operation on these lines. Further, there were, under order, 6 additional sets of this same equipment, which will be assigned to the Western Lines and which will complete the purchasing of these particular sets. For its 8000 miles of main track, the Southern will have an ultimate total of 18 sets of equipment and gangs similar to the one observed.

It is the intention of the Southern to operate these units on a five-year cycle. Realizing that a five-year cycle will require removal of ties in which there is still some worthwhile life, the Southern adopted a practice of salvaging and reinserting the usable ties in various secondary tracks.

For information, there is given below the cost of the power equipment in use by this gang. The prices shown were current at the time of the committee's inspection. In items where two pieces of equipment are shown, the price should be divided by two for unit cost.

2 Ballast equalizers	$23,750
1 Road crossing router attachment	2,500
1 Hydraulic spike puller	2,380
2,600-cfm, 16-tool tamping machines	88,000
1 Combination nipper-spiker	16,500
2 Combination tie remover-inserters	73,000
1 Track-lining machine	9,800*
1 Jack carrier cart	1,750**
1 Ballast broom	8,500

* Price of crawler-type machine. No price set on the on-track liner.

** Old price shown. New model to include safety stops on front of machine. Approximately $250 possible increase in price.

All of these highly mechanized gangs are, or will be, housed in trailers. The trailer distribution is planned to be as follows:

1 foreman and 2 assistant foremen—1 trailer
9 machine operators and helpers—2 trailers
15 laborers—3 trailers
Dining—1 trailer
Cooking—1 trailer

Each gang has two 2½-ton stake trucks assigned to it and can call upon a motor pool for additional trucks when it may be necessary to move a trailer camp from one location to another.

All of the trailers are equipped with electric lights, oil heating and hot and cold running water. The current for lights and power is supplied by a central generating plant which accommodates the entire group of trailers.

Some of the specific equipment adaptations and uses are noted below:

1. To start the daily operation, a ballast equalizer is used to rout the ballast from both ends of ties which are to be removed. This machine spends the morning accomplishing this work and is then used in the afternoon for final ballast equalizing work behind the gang operation. Incidentally, the operator used on this piece of equipment also has adequate time to operate the ballast broom.
2. The spike pulling operation is handled in the usual manner through the use of a hydraulic spike puller, but the helper used to operate this piece of equipment also recovers spikes which have been pulled and removes rail anchors. A spike keg carrier has been added to this piece of equipment and appears to be a very satisfactory arrangement.
3. The tie renewal operation performed by the tie remover-inserters includes clamping of and raising the rail to facilitate removal of the tie plates. This track raising, performed through extending the two vertical hydraulic rams located on either side of the machine, serves also to increase the opening under the rail for both the removal of the old tie and the insertion of the new tie. The removal is performed by an endless chain attachment, one end of which is brought against one end of the tie to be removed. The movement of this chain is continued until the tie has been shoved completely out from under the track. The tie which has been removed is picked up by a laborer handling a set of tongs attached to one end of a cable connected to a small hydraulic hoist and placed on a small tie car, about the size of a push car. This loading operation is continued until a total of 16 ties have accumulated on the tie car, at which time the ties are banded at each end into a bundle. The bundle is then dumped

off the car to the side of the track for a later pick-up by a crane in a work train operation. While this tie loading work is being progressed, a second laborer attaches a new tie to the end of the continuous chain, places one wooden plug in one of the pre-bored holes at the forward end of the tie, and then, more or less, hangs the tie plate on this wooden peg. The tie machine operator then pulls the tie into its proper place. The man handling the loading of the ties then applies the second tie plate before the track is again let down.

4. Spiking is the next machine operation and is handled by a single operator who can, with his machine, nip the new tie and, at the same time, spike it. A gaging operation, if necessary, is performed in advance of this work and is handled by the men who are doing the spike setting.
5. The succeeding item of work is handled by the gang foreman and consists of raising the track to the desired grade. In this operation it is the intention to obtain a maximum raise of 1½ in at the high spots and to pull the sags between these high spots up to grade. A multiple jack system is used, involving a total of thirty-six 5-in raise jacks. No grade or ballast stakes are set. The supply of jacks for the raising work is maintained by a semi-automatic, 4-wheel, gasoline-propelled jack carrier which carries the jacks from the tamping units to the track raisers.
6. Following the spiking work, there is a ballast-equalizing machine to which is attached a road-crossing pavement router. This machine pulls pre-dumped ballast off the shoulder and into the track center in preparation for the tamping work. The pavement router attachment is used to excellent advantage at road crossings and eliminates an excessive amount of hand digging and pick work.
7. The succeeding operation, consisting of tamping the track, is handled by two 600-cfm tamping machines in a tandem set-up in which each machine tamps every other tie. The jacks are removed from track at the time the first tamper reaches their location.
8. The next operation is the use of the mechanized track liner. Originally, an off-track model, mounted on endless treads, and which could crawl down the track in the space between the rails, was used. The new version of this machine is track mounted and appears to work in a more satisfactory manner. In conjunction with this work, a telescopic lining instrument is used. A separate target, which can be clamped on the rail, is used as a foresight and is placed at a location where line has been established. Another target is attached to the machine. This target is brought in line through operation of the track liner, resulting in excellent alinement.
9. To complete the gang operation, a ballast equalizing machine and a mechanical track broom are used, respectively, to equalize the shoulders and to remove excess ballast from the tops of the ties. The two machines combined gave some remarkably satisfactory results.

In addition to the foreman, an assistant track supervisor is assigned to the gang; he is held responsible for the complete operation. There is also, specifically assigned to this group of machines, one equipment maintainer whose duty it is to make all running repairs and who will, and does, work Saturdays and Sundays if necessary. This man has a specially equipped truck in which he keeps tools and replacement parts, and behind which he tows a trailer containing his electric and gas welding equipment and supplies.

During the day, and while work is being progressed, all trains that would normally operate are passed over the track on which the work is being performed. A restriction

(Text continued on page 409)

Condition of track prior to operation of mechanized gang.

Machine used for plowing ballast.

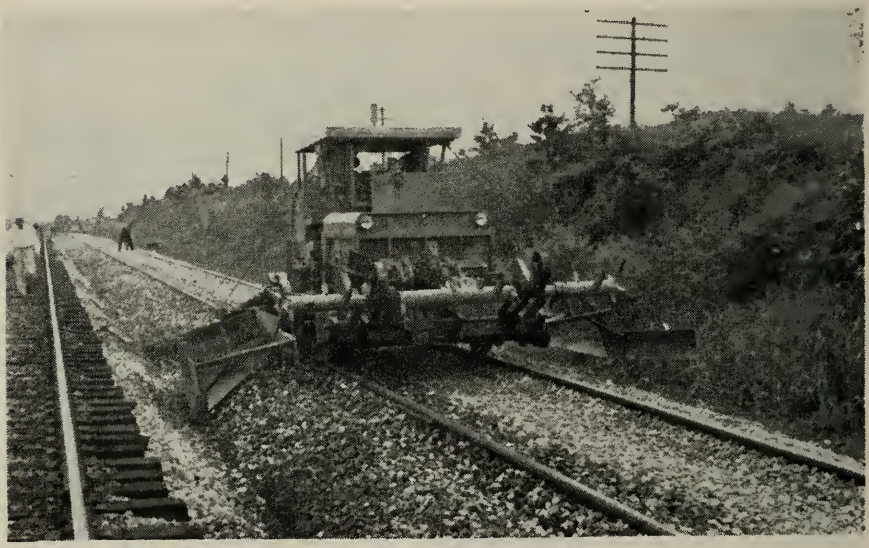
Spike puller. Note keg carrying attachment.

Tie remover—inserter used with mechanized gang.

Tie remover—inserter in position for operation. Note endless chain at lower right following tie removal.

Two multiple tampers in operation.

Close-up view of multiple tampers.

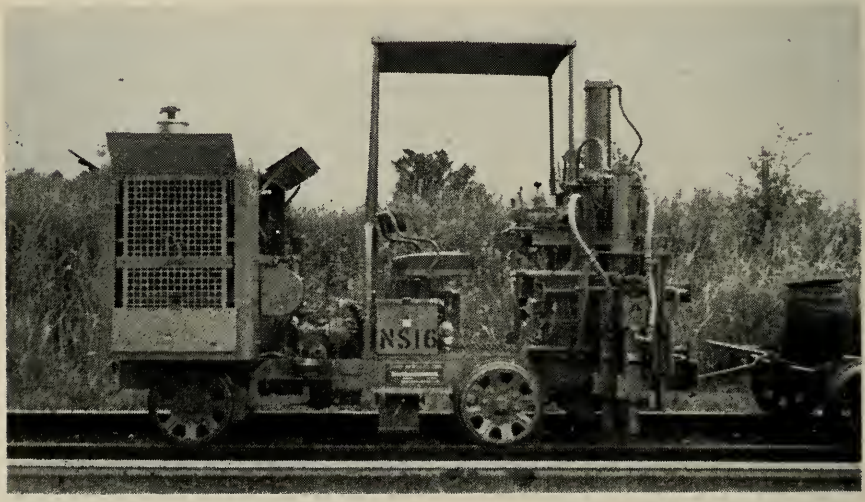


Ballast regulator with pavement scarifier attachment.

Track broom.

View of track after completion of surfacing–tie renewal operation.

New model on-track track liner.



Spiking machine.

View of all equipment in use in normal operating sequence.

of 20 mph is maintained during working hours, but the track is left in shape for normal speeds over night and on weekends. The Southern is making excellent use of radio communication. It is the intention eventually to eliminate human flagmen through the use of radio. This proposed method of handling contemplates that trains will be "talked" into and through the area where the gang is working. It would appear that this will result in gratifying labor economies and would give much less delay to trains.

Asphalt—Sand Tie Plugs

A question was asked the Southern people about placing tie plugs. They advised that they had discarded use of tie plugs and were using a mixture of hot asphalt and sand which is pumped into the spike holes through four separate tubes positioned correctly to accommodate the four spike hole locations. At each tie, on one side, a single insertion of the tubes is all that is necessary. With this method of plugging the holes, all voids are completely filled, and the exposed wood fibers are more or less permanently sealed insofar as moisture and air weathering are concerned. It was indicated that the asphalt hardened sufficiently by the time the spiking operation was performed to prevent spikes from seeking the old spike hole at those few locations where spiking had not been standard. For respiking at a later date, the filled spike holes would naturally be hardened to the point where the spiking operation would not be affected by the fact that an old hole existed in close proximity to the new spiking effort. One of the greater economies in this operation is in labor. Instead of the six, or sometimes more, men used to insert plugs on a rail relay, a single operator performs the entire operation. A considerable tie economy is also a factor in that the asphalt mix preserves the tie to a greater degree than a tie plug.

It was felt that descriptions of some of the Southern's new, and in some cases experimental, equipment would be quite interesting even though their development is not, in all cases, complete. Such descriptions follow.

Southern Railway's Shop-Made, Crawler-Mounted, Rail-Laying Crane

The Southern has taken a crawler-mounted tractor, removed all the hydraulic dozer attachments therefrom, and has converted it into an off-track rail laying crane, into which has also been incorporated a hoist to be used for removing the heavier pieces of on-track equipment in use with its rail laying extra gang.

The crawler treads are equipped with pavement shoes and the overall design of the completed machine is such that one set of treads walks on the ends of the ties outside one rail, while the other set of treads walks on the ties between the rails just inside of the other rail. A remotely operated vertical hydraulic ram arrangement has been placed on the front and the rear of the machine. At the end of the piston of this hydraulic ram there is mounted a double-flanged wheel of special design which fits over the ball of the rail which is not being removed. This double-flanged wheel eliminates the need for the operator to do any steering. It also rigidly and precisely locates the machine with reference to the fully spiked rail. Along the outside running gear of the treads that travel between the rails there is attached an adjustable flat steel plate. This plate acts to guide each rail being laid into precise gage position.

The actual rail laying attachments amount to a superstructure arrangement consisting of a hydraulic ram having approximately 7 ft of travel, to the end of which is attached a fulcrumed lifting arm that operates in about the same manner as a person's forearm. At the end of this extended arm there are rail tongs, also hydraulically controlled by the operator, that will reach out upon the shoulder, pick up a rail, lift it, move it toward the above mentioned side plate and then place it on the tie plates in perfect gage position.

Mounted on the rear of the machine is a vertical boom and a T-head braced lifting boom which is a part of the vertical boom. This entire arrangement is hydraulically operated and of such strength that it can lift off the track any of those heavier roadway machines which cannot easily be removed by hand.

This piece of equipment is well engineered, shows good thinking and is quite practical. Its operation on the track was not viewed, but the potentialities of its use were quite clear. The speed with which rail can be laid with this adapted tractor was said to be 30 sec per 39-ft rail. Its greatest advantage is, of course, that it is a piece of off-track equipment and can be moved off the track at virtually any location. Incidentally, the rail crane attachment does have horizontal travel, hydraulically controlled, that will allow the operator to move the piece of rail he has in lifted position a total distance of about 3 ft forward or backward in line with the track.

Labor economies of this particular machine, while possibly not as great as those to be noted in the other experimental machines, are quite noteworthy. It eliminates the three men who are required in handling the rail for a crane operation. One thing that should be pointed out is that the majority of the experimental machines being developed for use with rail laying gangs are of the type that can be most readily used on one rail, but with a bit more difficulty on the opposing rail. This development apparently represents the Southern's thinking so far as rail relay work is concerned. In this connection, this company uses two separate rail laying gangs, one of which lays rail approximately 20 to 30 rails in advance of the second rail laying gang. Each gang has the responsibility of laying rail on one side only and each of these machines is designed for a one-sided operation. In other words, two of the machines being developed would be required for each rail laying operation.

Southern Railway's Combination Nipper-Gager-Spiker

At the time of the committee's visit to the Southern's equipment shop at Charlotte, the road was in the process of adapting and constructing a machine that is probably most aptly described as a combination nipper-gager-spiker.

Initially, this piece of equipment was a mechanical nipper-spiker, commercially marketed, that will nip a tie and drive four line spikes, two at each end of the tie, at the same time. The operator stands in the approximate center of the machine where he has a view of the tie clamping and spiking operation and is in a position to make whatever minor adjustments may be necessary to accomplish necessary spike driving on a particular tie.

The Southern was in the process of constructing the experimental machine described in the heading and was using a nipper-spiker as the basic foundation for its new development. In the adaptation, the number of nipping arms had been reduced by one-half, leaving only two of them which were positioned adjacent to one rail. One-half of the spiking hammers, those on one side, had been removed, and only those two spike hammers over the one rail were being retained. Added to this machine were two horizontally placed hydraulic rams that could be operated to force the rail inward or outward by applying pressure at the rail base. There were means incorporated to obtain a perfect gage indication for the rail which was to be gage spiked. The operator's location had been changed from the standing position about the center of the machine to a seated position in a bucket seat located immediately above the rail being line spiked, and also located at the extreme end of the machine at a point where the operator might have easy and ready visibility of the spiking and gaging operation. In addition to hand controls, the machine is equipped with two foot treadles, one of which controls the forward and backward movement of the machine, while the other controls the lifting and dropping of the spiking heads.

It is the intention of the Southern to use this particular machine especially for gaging and line spiking rail in conjunction with rail relay operations. With one operator, such a machine would eliminate the need for the 12 laborers normally used to accomplish this work. For the intermediate spiking and completion of line spiking work, the ordinary nipper-spikers would be used. This particular piece of equipment had been given an operating test and, according to the Southern officers, had performed in a very satisfactory and gratifying manner. One thing to be pointed out is that precision gaging is assured. Spikes used for the gaging operation would, as a part of the overall operation, be fed directly to their proper locations and held, temporarily, in position for the actual act of spiking.

Southern Railway's Combination Single Wheel Cribber—Triple Adzer—Creosote Applicator

This piece of equipment was considerably beyond the test stage when viewed, and had been used and had given satisfactory results on at least one rail relay job. Advice has more recently been received to the effect that this machine is now being manufactured commercially.

This piece of equipment is rail mounted on one rail, and its travel along that rail is controlled by a set of double-flanged wheels. It is also supported at a point between the rails with a crawler tread arrangement that provides the locomotion power. The entire machine is hydraulically operated and has a 30-gal capacity hydraulic pump, the primary purpose of which is powering the three adzer heads but which, secondarily, powers the cable cribbing drum and creosote spray.

At the front end of the machine there is a heavy drum with numerous cable attachments designed to accomplish the maximum job of cleaning the tops of the ties and also to perform a cribbing job between the ties preparatory to the operation of the adzers. Immediately behind this ballast brush there is located a set of feeler teeth attached to an endless chain. These teeth, while not directly powered, rotate in an endless track fashion and provide the basis for gaging the depth of the adzing cut.

Immediately behind these teeth, the three adzers are mounted in line. The first adzing head makes a heavy rough first cut; the second adzing head completes the rough cut, while the third adzing head does the finishing work. In this adzing operation, the Southern does not attempt to cut the ties below the established bearing surface of the tie plates just removed. However, the adzing operation does eliminate all excess wood projecting above the bearing area. All the adzing heads operate at the same speed and have the same source of power transmitted separately, through horizontal sheaves, to each adzer head off a central vertical shaft.

Immediately behind the adzer head assembly, there is placed an automatic creosote sprayer that sprays creosote on the freshly adzed ties.

This single machine eliminates the need for six men on so-called "rock knockers", three adzer operators, one helper and one creosote machine operator. In their place one machine operator is used. This piece of equipment can be started in motion and will proceed at a pre-set pace, and it is not necessary that the operator ride it. While the machine is performing its assigned work, the operator has time to work over spare adzing heads, replacing the teeth therein that have been worn or broken. He has sufficient time to do this before it is necessary to make a change-out of all the adzer heads.

In addition to the quite notable manpower savings represented by this piece of equipment, there is also a remarkable improvement insofar as safety is concerned. This particular machine, with a single man in charge, minimizes, to the greatest extent, the possibility of injury always present in the operation of a number of smaller machines.

Southern Railway's Multiple, 16-tool Tamper Adapted for a One-Man Track Raising Operation

At the time of the committee's visit to the Southern's Charlotte maintenance of way shop, the road had constructed 4 of the machines described below and has plans for eventually constructing 17 identical machines.

In this case the Southern has taken one standard type, tamping machine and has applied two 6-in by 6-ft (approximate) vertical hydraulic raising rams at the front end at the approximate location of the tamping heads. Coupled with these are some lifting arms, of break-over type construction, that go downward and inward, pushing themselves under the base of rail when the rams are forced downward into the ballast. As the vertical rams are extended and the front end of the machine starts raising, the lifting arms pull the rail and ties upward at the same time. As a part of this arrangement, the Southern has installed a dial-like indicator located in front of the operator and slightly above his eye level. An indicator needle, designed to travel over the face of the dial, gives the operator an indication of the amount the track is out of cross level. This needle forms the extension of a pendulum, fulcrumed properly, which is itself suspended in oil for stability, and gives a direct reading to the operator and interprets for him cross level conditions at a certain point.

It is the intention of the Southern to use this adopted tamping machine for trouble shooting work where minor cross level conditions are giving a rough ride. In other words,

the equipment would operate like a section force and be used for correcting minor rough track conditions at widely separated locations, with no intention of using this particular equipment for any heavy out-of-face work, although it could also be used for this purpose. It is the intention to provide highway trailers for the tamper which will be used for transporting it from one location to another. These highway trailers are 2-axle, 4-wheel trailers of the lowboy type, and the towing vehicle has a winching arrangement that is used for loading the tamper. Short sections of ramp rail are provided, and the trailer bed has rails placed on it, with the necessary rail stops, so that the tamper can be pulled upon the bed of the trailer easily and quickly. The Southern people indicated that the tamper can be both loaded and unloaded in the total time of 6 to 8 min for each operation.

The only personnel used and required with this piece of equipment is the operator and the foreman. Flagman to protect its operation would be optional in view of the fact that the Southern is relying heavily upon radio communication between on-track gangs and trains. In fact, few of its gang operations have flagman protection. Train crews are given positive orders about approaching gangs working at particular locations and are required to obtain permission from the foreman via radio before proceeding beyond a certain point. They are making radio pay off in quite considerable savings in their gang operations, both insofar as use of minimum personnel is concerned and also as regards overall delay to gangs and trains.

As can be seen, this adapted tamping machine, with a two-man operation, replaces and can do the work of, a gang of 8 to 12 men, depending upon the amount of work at particular locations and the number of times the machine must be loaded and unloaded during each day.

Southern Railway's New Tie Unloading Machine and Special Tie Car

The Southern Railway has been developing a tie unloading machine and special tie car during the past year and a half, and it can be said that the practicability of this equipment for unloading ties has been proved insofar as this road is concerned. It now plans to construct approximately 6 additional sets of these cars, of 12 cars each, and will attempt to obtain additional tie unloading machines as soon as the manufacturer can make them available.

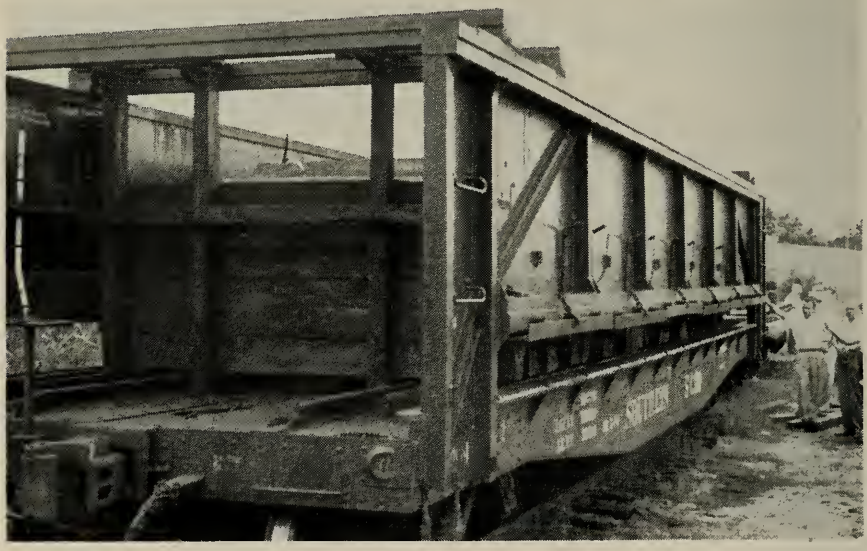
This particular tie unloading machine is a development of the Southern and has now been turned over to a railroad supply firm for refinement and commercial manufacture. The manufacturer has indicated that it should have the first commercial machines ready for the market some time in November or December 1955.

The accompanying pictures show fairly well the construction of the special tie cars and also the manner of operation of the tie unloader.

It should be pointed out that in the special tie cars the framework placed in the open ends is easily removable and is placed there primarily to prevent the ties from shifting during transport. In addition, it should be pointed out that the small trap doors located along the bottom edge of the sides can either be raised or lowered as the situation requires.

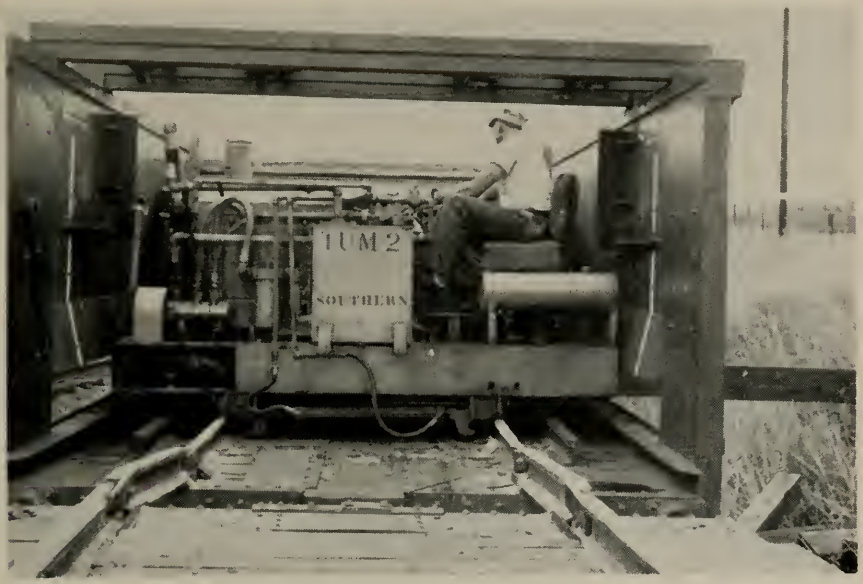
It should also be noted that there are two sets of rails running the length of the car. One of these provides the traveling or running rail for the tie unloader while the other set of rails provides the flooring for the tie load. It was the thought that if the ties are set on top of the rail, they could be skidded laterally much more easily than would be the case if they were resting on a solid floor. The running rails are spaced so that a tie has a certain amount of support under it at all times as it is being removed from the car.

The Southern's tie unloading machine.



One of the Southern's special tie cars.

The two small rollers seen, one at each side of the front of the tie machine, and located in line with the two vertical columns, hold the rear end of the tie down and prevent it from kicking upward, which would cause it to bind as it is pushed through the opening along the side of the tie car. The main purpose of the vertical members on the front of the tie unloader are for the protection of the operator as they will prevent highly piled ties from rolling over on top of the machine.



Tie unloading machine in operation.

The committee was advised that the tie unloader can unload a car of 400 ties, when standing in one spot, in 17 min; when performed in a work train and placing the ties at scattered locations, but in a precise manner, the operation of unloading a car of 400 ties consumes 45 min.

It should be pointed out that when the ties are unloaded from a work train, the operation can be so well controlled that the ties will be unloaded at the exact position where needed, at right angles to track and with no need for them to be unloaded anywhere but on the ballast shoulder. The force of ejecting the ties can be so well controlled that they can be dropped on the shoulder with no danger of them going down the slope.

All the personnel required for the complete operation consists of one operator in the cars and one man, preferably a supervisory employee, on the ground. In view of the fact that the machine operation in the car produces a considerable amount of noise, the unloader is equipped with radio and the supervisory officer on the ground carries a walkie-talkie. With this arrangement, shouted orders are unnecessary and there is no excuse for the operator not receiving instructions to drop the tie at the location desired. At the same time, the supervisory officer can control, through use of the radio, the speed and operation of the work train or local, whichever the case may be, because the engine is also equipped with the necessary radio receiving equipment.

When only two men are required for unloading ties, the labor saving economies can be quite readily seen. In addition, the tremendous betterment in the safety picture is also a factor that would, over a period of time, easily result in as great a savings as would the actual labor economies.

To accomplish the same results that can be obtained with the tie unloader, a force of 12 to 15 laborers would be required. The machine would not necessarily have to be assigned to a particular operation but could be used at several locations and satisfy

a need at these several points over the same period. For full utility of the tie unloader, it would possibly be necessary to assign to it 36 to 40 of the special tie cars. Only thus could the full economies of the tie unloader operation be realized. The Southern people have indicated that the special tie cars could be constructed, or converted, for a cost of about $3,000 each, with the possibility that an expanded car construction program might further reduce the unit cost per car. In view of the fact that the tie unloader was still on the manufacturer's drawing board, no estimated cost for this machine could be obtained.

Southern Railway's Proposed Tie Plate Distributing and Placing Machine

The Southern officials advised the committee that they were ready to start development of a machine that would handle containers loaded with tie plates. This machine would accept tie plates from the container one at a time, place them right side up, square them and set them precisely on the tie at the location desired, completing the operation with a stapling effect that would temporarily hold the tie place in position until the rail is laid.

In connection with this, it is their plan to devise special gondola cars equipped with a complete nest of individual containers that could be forwarded to the steel mill for tie plate loading. The tie plates would be loaded by the steel mill in this car in the same manner as they would load an empty gondola, filling each container as the loading progressed. The car would then be forwarded to the point where the rail was to be relayed, and the containers unloaded one at a time by a rail crane on the shoulder at pre-determined locations. The tie plate handler would have a boom arrangement that would allow it to pick up a container of tie plates, empty the container into a special hopper, and from that point a machine method of distributing and placing would take over.

In this manner of handling, no human hands would touch the tie plates from the time they left the steel mill until they were placed upon the tie. The planning as related sounded quite feasible, but in view of the fact that no positive construction effort had as yet been made, no exact description of the design of the piece of equipment could be obtained.

If such a machine is practical, the potential labor savings are quite considerable. Such a machine could quite feasibly replace 12 to 15 laborers when the tremendous amount of hand distribution presently given to placing tie plates is considered.

CONCLUSIONS

In conclusion, based upon the operations seen and information obtained, it can be stated that the Southern Railway System has, in a very successful, efficient and gratifying manner, through precise assignment and allocation of men and machines working together in a well planned and highly comprehensive manner, effected maintenance-of-way labor economies that are very considerable in nature; through their well planned units of organization, they have contributed heavily toward greater improvements and betterments as regards track maintenance operations; and their stated intentions are to continue to progress their present feeling that the possibilities of obtaining additional worthwhile labor economies are still present in as high a degree as has been the case in the past.

Report on Assignment 3

Comparative Economy of Routine Track Maintenance with Limited Size Forces, and Cycle, Out-of-Face Track Maintenance with Fully Mechanized Forces

N. M. Kelly (chairman, subcommittee), M. B. Allen, J. F. Beaver, R. H. Carpenter, A. B. Chaney, P. A. Cosgrove, C. G. Davis, M. H. Dick, J. E. Eisemann, H. J. Fast, J. L. Fergus, W. H. Freeman, E. B. Harris, G. L. Harris, W. W. Hay, W. H. Hoar, G. W. Hunt, T. B. Hutcheson, C. Johnston, H. W. Kellogg, R. Lumpkin, H. C. Minteer, J. P. Morrissey, J. A. Pollard, M. S. Reid, L. H. Rose, R. R. Smith.

This is a final report, submitted as information.

As this subject is an extensive one, which cou'd be studied indefinitely, it is covered in this report only from the points of view of smoothing track,* and renewing ties, each operation in its own cycle. The comparisons made are between the number of man-hours used in carrying out track smoothing and tie renewals by section forces, with lengthened territories or otherwise, and the number of man-hours used in carrying out the work during the same or changed cycle by fully mechanized "district gangs"**.

Since this subject deals with track maintenance, and encompasses primarily the economics of labor in connection therewith, reference is made to previous reports of Committee 22, particularly to its reports on Assignment 2—Analysis of Operations of Railroads that Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work. No reference is made to any report presented prior to 1943, as it is felt that they would be out of date, particularly with respect to economies to be derived from mechanization and organizations.

In considering this subject particular reference should be made to the following reports on Assignment 2 of Committee 22:

1. Proceedings, Vol. 44, 1943, page 671: Outlines how the Illinois Central reduced labor requirements over a 15-year period by physical improvement of roadbed and track, better organization of maintenance forces as reflected by the reduced number of sections and divisions, and the mechanization of operations.
2. Proceedings, Vol. 49, 1948, page 136: Shows how the D&H reduced maintenance costs by the use of welded rail.
3. Proceedings, Vol. 50, 1949, page 226: Shows the economies derived by the DL&W by performing certain major items of track work by large gangs on dead track with traffic detoured, as compared to performing similar work with smaller gangs on live track under slow orders.
4. Proceedings, Vol. 51, 1950, page 310; Outlines the economies derived by the Pennsylvania from mechanized methods of roadway and track maintenance with carefully planned work and using correct power machines on projects for which machines are best suited.
5. Proceedings, Vol. 52, 1951, page 322; Sets forth the economies derived by the EJ&E from mechanized yard cleaning methods.
6. Proceedings, Vol. 53, 1952, page 352: Gives a very good report on the economies derived from doing away with small section crews and using district gangs on the ST L–SF.

* Spot or selective surfacing of track.
** Gang assigned to a division.

7. Proceedings, Vol. 54, 1953, page 757: Gives a further report on the dead track detour method (Vol. 50) as used by the DL&W.
8. Proceedings, Vol. 55, 1954, page 524: Outlines the economies derived by the AT&SF from renewing ties with special mechanized gangs without a track raise instead of using section gangs.
9. Proceedings, Vol. 56, 1955, page 455: Sets forth the economies derived from reorganization of forces and intensive use of labor saving machinery on the C&O.

Other Committee 22 reports to which reference should be made are as follows:

1. Proceedings, Vol. 49, 1948, Assignment 3—New Methods and Labor Saving Equipment to Offset Increased Costs.
2. Proceedings, Vol. 53, 1952, Assignment 4—Labor Economies of Various Methods of Tamping Track.
3. Proceedings, Vol. 54, 1953, Assignment 3—Organization of Forces for Track Maintenance Operations.
4. Proceedings, Vol. 55, 1954, Assignment 5—Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization.

Information for this present report was obtanied from a questionnaire sent out by the committee to 103 railroads in the United States and Canada concerning their present practices; completed questionnaires were received from 34 railroads. Several railroads declined completing the questionnaire because they are short line railroads or because their systems of accounting prevented giving any reliable figures. A comparative statement of all the railroads which completed the questionnaire is given in the accompanying table, which includes data on sections, number of district gangs, tonnage and cycle.

Of the railroads reporting, the average length of section is 16.9 miles with an average force of 6.4 men, which indicates a trend toward the lengthening of sections due to a higher degree of mechanization than in previous years. Fifteen railroads use mechanized district gangs. Ten of these railroads use both section and district gangs for both tie renewal and smoothing work, with one railroad using section forces for smoothing and district gangs for tie renewals. Another railroad has section forces doing both smoothing and tie renewal work, with a district gang aiding in making the tie renewals. One railroad employs section forces for smoothing, with a district gang aiding in smoothing and doing tie renewals. Another railroad uses district gangs for both jobs, and still another railroad is in a period of transition. The remainder of the reporting railroads still use section forces for both jobs.

Of the railroads using mechanized district gangs nearly all have increased their cycle of tie renewals from annually to between 5 and 8 years, and the cycle of smoothing has also been increased, but to a lesser extent than that of the tie renewals. The railroads using section gangs still renew their ties and spot surface annually, or as required.

Although the increased cycle and mechanization of forces has been recent to all railroads, their methods of doing the work were changed because of the following reasons:

1. Higher production per man day.
2. Economy, efficiency and reduction of the number of foremen.
3. The inauguration of the 40-hr week.
4. High cost of labor.
5. Better quality of work.
6. To concentrate forces in order to equip them with power tools.

7. To derive benefit of power tamping over hand tamping.
8. To increase length of sections.
9. To reduce delays in heavy traffic.

A gradual change has been and is being made in the allocation of tasks to track gangs. Section gang territories are being made longer and can be handled with smaller forces doing such work as spot work, unloading material, switch inspection, fence and road crossing repairs, patrolling, tightening bolts, mowing weeds, and other housekeeping chores on 12 to 15 miles of track. The mechanized gangs, whether district or section gangs doubled, with the use of power machinery and an increased cycle can perform such work as out-of-face tie renewals, smoothing, reballasting, etc. Changes are still in progress, and organizations will have to be set up to suit local conditions, as these vary on different railroads and even on different districts of one railroad. Local conditions also decide whether men, equipment and material are transported by truck or rail.

One railroad reports that in carrying out a new out-of-face ballasting operation, putting the track up on 6 in of new stone ballast, tie renewals are made for the current year and the following two years so that the track will not be disturbed for three years. It is endeavoring to work into a two-year cycle where ties are renewed on half of a roadmaster's territory each year by mechanical tie gangs, with some help from the sections. It is the intention to carry out smoothing in the same fashion and cycle. It is hoped, in this manner, that no tie renewals or smoothing will have to be done by the section gangs except spot work.

Most railroads reported that the equipment used by the section gangs consists of the usual hand tools, while a few railways have section gangs using 4-tool power tampers. A great variety of different machinery was reported to be in use by the mechanized district gangs, and no attempt has been made to list it here.

An attempt was made in the questionnaire to get data to compare the number of man-hours used in carrying out tie renewals and smoothing by section forces, with lengthened territories or otherwise, and the number of man-hours used in carrying out the work during the same or changed cycle by fully mechanized district gangs. Most systems of accounting on the railroads do not provide a break down of the labor spent on tie renewals and smoothing, and as a result most answers were estimated or no figures were given at all. With respect to tie renewals, the figures do indicate that mechanized section gangs show a slight saving over section gangs using hand tools, and that mechanized district gangs produce even greater savings. The figures given by the different railroads on smoothing varied greatly because of their different types of weather, ballast, rail, etc., and density of traffic and tonnage. However, for each railroad individually there was a very definite saving produced by performing this work with mechanized district gangs as compared with doing the same work with section gangs, either with hand tools or mechanized equipment.

CONCLUSIONS

As very few replies were received from the questionnaire, it is apparent that cycle maintenance has not been fully adopted by many railroads and, therefore, nothing conclusive can be drawn from the figures given. Perhaps this subject should be brought up again at a later date when more railroads have had experience with cycle maintenance.

However, it appears that savings can be made from cycle maintenance by district gangs, with sections lengthened and forces decreased. The section forces should be mechanized only to economic necessity and used to perform spot work, with the fully mechanized gang doing all heavy out-of-face work.

STUDY

"Comparative Economy of Routine Track Maintenance with Limited Size Forces, Cycle and Out-of-Face Track Maintenance, with Fully Mechanized Forces"

Name of Railroad	Division	AREA Equated Track Miles	Total No. of Sections	Average Miles per Section	Laborers per section Including Foreman	Number of District Gangs	Average Annual Gross Million Tons	Tie Renewal Cycle	Smoothing Cycle
The Texas & Pacific Railway Co.	Western	650	45	11.5	6.3	2	10.466	5-7 years	5-7 years
Maine Central Railroad Co.	System	1259	121	10.4	5	6	Unknown	Annually	Annually
The Chesapeake & Ohio Railway Company	Huntington	1093	53	14.5	5	None	Unknown	3 years	No cycle
The Chesapeake & Ohio Railway Company	Detroit	163	5	29	14	None	Unknown	No cycle	4 years
Chicago, Rock Island & Pacific Railroad Co.	Rock Island	369	17	10	4	6	12.012	Annually	Annually
Louisville & Nashville Railroad Co.	Birmingham	1637	None (Truck & patrol gangs	-	-	7	Unknown	5-8 years	as required
Louisville & Nashville Railroad Co.	Eastern Kentucky	504	25	20.2	5.6	2	24.12	As required	As required
The Monogahelia Railway Co.	System	133.7	12	15.5	5	1	1,020.*	6 years	6 years
Spokane, Portland and Seattle Railway Co.	Vancouver	518	36	14	4	None	4,362.2*	-	7 years
Chicago and Northwestern Railway system	Galena	743.6	85	10	4	None	5,457.4*	as required	as required

*Average Annual Gross Million Ton Miles

STUDY (Cont'd)

"Comparative Economy of Routine Track Maintenance with Limited Size Forces, Cycle and Out-of-Face Track Maintenance, with Fully Mechanized Forces"

Name of Railroad	Division	AREA Equated Track Miles	Total No. of Sections	Average Miles per Section	Laborers per section including Foreman	Number of District Gangs	Average Annual Gross Million Tons	Tie Renewal Cycle	Smoothing Cycle
Burlington Lines	Lincoln	567	45	12.6	4	None	1,016.1*	No cycle	No cycle
Central of Georgia Railway Company	Macon	633.7	31	20.4	6.4	3	2,264.6*	4-5 years	4-5 years
New York Central System	System	14,900	700	20	6	-	-	7-8 years	3-4 years
Rutland Railroad Corporation	System	442	14	30.1	7	0	525.9	-	4-5 years
Birmingham Southern Railroad Co.	-	25.15	2	12.57	16.5	0	7.5	5 years	3 years
Illinois Central Railroad Co.	Springfield	845.1	52	16.25	5	None	571	Annually	As required
Green Bay and Western Railway Company	Kewaunee to Winona	321	21	15.3	6.5	None	608.4	Annually	Annually
Missouri Pacific Lines	Central Kansas - Colorado	815	52	13.3	5	-	4,499.8*	Annually	As required
Missouri - Kansas-Texas Lines	Cherokee	139.5	12	9.5	4	None	456.5	No cycle	No cycle
Reading Lines	Philadelphia	981	24	23.7	9.25	12	-	5 years	-
C.P.R.	Bruce	498.1	61	6.6	3	None	1,355.8*	Annually	As required

*Average Annual Cross Million Ton Miles

STUDY (Cont'd)

"Comparative Economy of Routine Track Maintenance with Limited Size Forces, Cycle and Out-of-Face Track Maintenance, with Fully Mechanized Forces"

Name of Railroad	Division	AREA Equated Track Miles	Total No. of Sections	Average Miles per Section	Laborers per section Including Foreman	Number of District Gangs	Average Annual Gross Million Tons	Tie Renewal Cycle	Smoothing Cycle
Detroit, Toledo and Ironton Railroad Co.	System	464.4	16	26	10	3	18.4	5-7 years	2-3 years
Western Pacific Railroad Co.	Western	735.3	49	15	5.1	None	4,041.5*	Annually	Annually
Deluth, South Shore, and Atlantic Railroad Co.	System	553	34	16	5	2	4	Annually	As required
A.T. & S.F.	Illinois	554	40	13.8	6.4	2	6,552*	3 years	As required
A.T. & S.F.	Missouri	497	40	17.5	6	-	6,600*	Annually	4-7 years
Great Northern Railway Co.	Cascade	490.9	26	18.9	5	3	2,258*	2 years	3 years
St. Louis, San Francisco Railway Company	Southwestern	587	16	37	14	-	-	7-10 years	as required
Mississippi Export Railroad Co.	System	38	3	14	5	-	-	No cycle	No cycle
C.N.R.	St. Thomas	460	40	7.5	4	2	4,995*	-	3-4 years
The Baltimore & Ohio Railroad	Cumberland	712	67	10.6	6	None	11,100 *	Yearly	Yearly
The Pennsylvania Railroad	Fort Wayne	460	22	23	10	None	6,720 *	5 years	Yearly
Elgin, Joliet and Eastern Railway Co.	Joliet	354.1	15	23.6	6.9	None	2,886 *	7-8 years	Continuous
New York, Ontario & Western Railway Company	System	432	36	13	5	-	1,070 *	As necessary	Various

*Average Annual Gross Million Ton Miles

Report on Assignment 5

Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization

L. A. Loggins (chairman, subcommittee), A. D. Alderson, M. B. Allen, J. F. Beaver, E. J. Brown, R. H. Carpenter, C. G. Davis, M. H. Dick, J. E. Eisemann, J. L. Fergus, W. H. Freeman, C. G. Grove, W. H. Hoar, T. B. Hutcheson, Roy Lumpkin, J. F. McCook, E. H. McIlheran, W. H. Miesse, J. P. Morrissey, R. W. Pember, J. A. Pollard, R. R. Pregnall, R. R. Smith, F. R. Spofford, P. V. Thelander, H. J. Weccheider, F. R. Woolford, C. R. Wright.

Your committee submits the following final report covering the study of methods, equipment and organization used in the replacement of track ties.

Thirty-four railroads furnished information outlining the methods, equipment and organization used to replace track ties. All of these roads use section gangs for at least part of the work. Twenty-seven use extra gangs in addition when making renewals incident to out-of-face resurfacing work. Eight—The Atchison, Topeka & Santa Fe; Boston & Maine; Chesapeake & Ohio; Minneapolis, St. Paul & Sault Ste. Marie; New York Central; Southern; Southern Pacific Lines in Texas and Louisiana; and Union Pacific use special gangs organized for the purpose of renewing some of their ties.

On practically all of these railroads ties are inspected, and those to be replaced are marked by section foremen, roadmasters or track supervisors and, in most cases, are also checked by other officers. On the Illinois Central an experienced maintenance of way employee, having specialized tie knowledge and accompanied by a section foreman or supervisor of track, makes the inspection and marks the ties to be replaced. On the Santa Fe a Tie Department inspector inspects and marks those ties to be renewed.

On most of the railroads reporting, ties are handled to the job site by work train or local freight when available. Otherwise, they are unloaded at stations or sidings and later distributed by track car. Ties are loaded loose and are unloaded by hand, except on four roads, where some ties are banded and handled by crane. All report the use of gondola cars, but some also use flat cars, box and stock cars to some extent. Special tie cars are used on the Santa Fe, NYC, WP and the Southern, and it is believed that after further study and improvement, the use of special tie cars will produce substantial savings. The reports indicate substantial savings to be made by unloading ties from work train or local freight at the job site instead of unloading at stations or sidings and later distributing by track car.

The use of specially organized and equipped tie gangs on six railroads indicates the following percentages in reduction of cost from the conventional method of doing the work with hand tools:

	Percent Reduction
Santa Fe	58
Boston & Maine	42
Minneapolis, St. Paul & Sault Ste. Marie	44
Southern	67
Southern Pacific Lines in Texas and Louisiana	36
Union Pacific	18

The Santa Fe, Southern and B&M gangs are equipped with more mechanical tools and produce greater savings than partially mechanized gangs on other railroads. One railroad reported the use of tie gangs with only hand tools which show substantial

savings over use of the ordinary section gang with hand tools because it was found that the gangs which perform tie renewals every day become more adept at it than those used periodically for the purpose. The Delaware, Lackawanna & Western handles tie renewals on a cycle basis and uses a highly mechanized, 70-man gang for heavy main-line tie replacements in connection with resurfacing work. This gang, on the average, resurfaces 120 rails per day with tie replacements averaging 700 per day. The practice on the DL&W is to remove all ties which will not last six or seven years, and many of the recovered ties are used in yard tracks. The roadmaster or supervisor marks the ties to be replaced. New ties are loaded loose in drop-end gondola cars and are delivered to the job by work train and unloaded with a tractor crane. Old ties are picked up in the same manner.

The Southern uses a highly mechanized 25-man gang, including 13 laborers and the necessary machine operators and supervision, to retie and resurface track. These gangs average replacing 288 ties per day while resurfacing 3800 ft of track.

The Missouri Pacific Lines report that by using hand-operated tie-pusher equipment with a 16-man gang replacing ties ahead of the resurfacing gang, the productivity of the gang was increased by 49 percent.

The Southern Pacific Lines in Texas and Louisiana report that the use of a hand operated tie remover and tie replacer with 4-man section gangs increases production by 53 percent.

CONCLUSION

This study indicates that substantial economies are to be gained by the use of properly organized and equipped gangs to renew ties. It is believed that other railroads will use special tie gangs and equipment for renewing some of their ties, will use special tie tools for replacing ties with section gangs, and will develop special tie handling cars. This will require time.

It is, therefore, recommended that this assignment be discontinued until further data become available on the subject.

Report on Assignment 7

Comparative Economy of Handling Maintenance of Way Gangs in Trucks Versus Motor Cars, Including Economical Length of Haul

Collaborating with Purchases and Stores Division, AAR

H. J. Weccheider (chairman, subcommittee), Lem Adams, M. B. Allen, B. V. Bodie, A. B. Chaney, P. A. Cosgrove, W. W. Edwards, R. J. Gammie, L. C. Gilbert, W. H. Hamilton, G. W. Hunt, G. A. Kellow, L. A. Loggins, Roy Lumpkin, J. S. McBride, J. F. McCook, E. H. McIlheran, J. P. Morrissey, G. M. O'Rourke, R. W. Pember, R. R. Pregnall, Jr., L. F. Racine, W. R. Rees, R. R. Smith, P. V. Thelander, H. M. Williamson, C. R. Wright.

This is a final report, submitted as information.

This particular subject, or ones very similar to it, have been previously reported in the Proceedings, in 1933, 1942 and 1946. The subject matter is brought up to date in this report, which covers data on the use of various types of highway vehicles used in maintenance of way and structures work, as well as the economical length of haul.

Information on the class of emp'oyees to which trucks are assigned, the special vehicles used, their operation, ownership, maintenance, number in service, economy derived, and advantages and disadvantages of using trucks was compiled from replies received from various railroads in the United States and Canada to a questionnaire sent out by this committee.

Fifty Class I railroads were requested to furnish information concrening their present practices, and replies were received from 46. All the reporting railroads, except 4, are using highway vehicles in some phase of maintenance of way work. The 4 exceptions are railroads which do not have sufficient highways in close proximity to their tracks due to their geographical location.

The upward trend in the use of trucks in lieu of motor cars by outlying maintenance gangs started in 1940. Up to that time the use of trucks had been confined principally to large terminal areas. Since that time, and particularly from 1945 to the present time, there has been a decided increase in the substitution of trucks for motor cars for transporting the various classes of maintenance and construction gangs indicated further on in this report.

The trend toward 100 percent transportation by highway vehicles is being realized on some railroads in the following categories: extra, seasonal track gangs, large yard gangs, district track gangs, district and divisional welding gangs, work equipment repairmen, system and divisional bridge and building gangs, water service and plumbing gangs, signal and communications department construction gangs, and engineering personnel.

In general, the use of trucks is more extensive on railroads east of the Mississippi River than in the western region of this country and in Canada, because of climatic conditions, highways more closely paralleling the railroad, and the denser railroad traffic in the east which makes it more difficult to operate track motor cars without loss in productive time. One southern railroad reports that it is 100 percent equipped with trucks for all classes other than yard gangs and flange lubricator maintainers. Another southern railroad reports that its extra track gangs, regular and district section forces, bridge and building crews, signal construction crews, and communications and electrical maintainers are 100 percent equipped with trucks. Two eastern, one western and one southern road report 100 percent truck use by extra track gangs, system and divisional bridge and building crews, signal construction crews, communications forces, engineering personnel, district welding gangs, work equipment repairmen and plumbing gangs.

One Canadian road reported that the use of trucks for transporting men and material for maintenance of way work has been very limited to date. Because of the climate and the geographical location of lines without roads in close proximity, and also the relatively short normal working season, the economic value of trucks over motor cars could not be demonstrated on a system or regional policy. It has been its practice, therefore, to evaluate the economics for each truck, the purchase having to stand on its own merits. In its larger terminals there is a pool service of trucks among departments, the maintenance of way department using the trucks only as required.

1. Truck Utilization Data

The following data were compiled from the various railroads' replies to seven pertinent points included in our questionnaire:

CLASS OF EMPLOYEES TO WHICH TRUCKS ARE ASSIGNED, PERCENTAGE USING TRUCKS, TONNAGE OF TRUCKS AND AVERAGE NUMBER OF MEN CARRIED PER TRUCK

Class	Percent Using Trucks	Tonnage of Truck	Average No. of Men Carried
(a) Extra track gangs (includes ballasting gangs, organized tie gangs, rail laying gangs, etc.)	62	1½–2	18*
(b) Regular section gangs	10	1–1½	5
(c) Large yard gangs	57	1½	11
(d) District track gangs	87	1½–2	19**
(e) District welding gangs	53	1½	5
(f) Division welders	32	¾–1½	3
(g) Work equipment repairmen	68	¾–1	2
(h) Flange lubricator maintainers	52	½–1	1
(i) Supervisory personnel	47	¾–Stn. Wgn.	2
(j) System bridge and building gangs	57	1½–2	11
(k) Division bridge and building gangs	63	1½–2	10
(l) Water service gangs	90	¾	3
(m) Plumbing gangs	63	¾	3
(n) Signal construction gangs	74	1½–2	9
(o) Signal maintenance forces	18	½–¾	2
(p) Communications construction gangs	81	2	7
(q) Communications maintenance forces	68	½	2
(r) Electrical maintainers	69	½–1	3
(s) Engineering personnel	82	Stn. Wgn.	3
(t) Other miscellaneous forces not listed above (equipment operators; m. of w. shop; bridge and tunnel inspectors; scale inspectors; scale gang)	96	¾ to 1½	3

*Four railroads use busses carrying an average of 34 men.
**One railroad uses busses carrying an average of 35 men.

2. Special Trucks Used

Many railroads purchase and use specially equipped trucks in maintenance gangs. Of the 46 railroads reporting, 38 indicated the use of special trucks, particularly by bridge and building, signal, and communications gangs, these trucks being equipped with power winches and "A" frames, and some being equipped with special bodies for the transportation both of men and tools and material. Others use specially designed truck bodies which permit the carrying and safe storage of expensive tools and material, small machines and spare parts.

Extensive use of ordinary dump trucks and trucks equipped with hydraulic lift gates for the transportation of material, and also for handling excavated material on special projects, is reported by several railroads.

Several railroads advise that they have combination track–highway vehicles with flanged wheels, which are used mostly as inspection cars, although some use of them has been made for the transportation of men on branch lines.

3. Operation

The average economical length of haul varies with the class of employees involved. From the various reports received, the length of haul for section gangs is 5 to 15 miles; extra track gangs, 3 to 30 miles; district track gangs, 25 to 50 miles; bridge and structures, signal and communications gangs, 10 to 25 miles; water service, plumbing, welders and engineering personnel, 25 to 100 miles.

Trucks are used for the transportation of both men and material.

In general, very little leveling of the right-of-way to permit closer operation of

trucks to the sites of the actual work has been done; however, 5 railroads have made this a major project and 12 others have reported some progress.

Railroads having paralleling roads, or highways which cross their tracks at fairly short intervals, report that trucks can be driven to within a distance of 25 yd to ½ mile from the site of the work. Most railroads in the Pacific Northwest have very few roads in close proximity to their tracks.

4. Ownership

The survey reveals that all the reporting roads, with the exception of 5, own their own vehicles. Two of these 5 roads own 80 percent of their trucks and rent the balance; 1 railroad owns 72 percent and rents the balance; 1 railroad owns 70 percent and rents the balance; and the other road rents all the trucks it uses.

One southwestern road reports the rental cost as $120 to $180 per month for the use of one 1½ to 2-ton truck, and $75 per month for a ½ to ¾-ton pick-up truck, plus a premium per mile over specific mileage. An eastern road pays $18 to $60 per week, plus 3 to 6 cents per mile, depending upon size and equipment.

The average number of trucks in operation, as indicated by the reporting roads, is 10 to 100 trucks on 20 roads, 100 to 200 trucks on 3 roads, 200 to 350 trucks on 5 roads, 575 to 675 trucks on 3 roads, 700 to 800 trucks on 2 roads. Nine roads did not report the number of trucks in service. Four roads do not use trucks.

5. Maintenance

Twenty-seven reporting railroads advise that records are kept of the operation and maintenance cost of their trucks; eight railroads keep no records, and one railroad advises that records were not kept prior to 1955; however, that very careful records are being kept this year.

Two reporting roads advise that all their maintenance is done in their own centralized shops; 12 roads report that a portion is repaired at their own centralized shops, and other portions in division shops and outside garages, whichever are the most convenient; 11 roads report that all repairs are made exclusively in outside garages; two roads report that a portion of their repairs is now being done by the mechanical department; while two roads report a portion of their repairs is done by a trucking subsidiary company.

Repairs to rented trucks are made by the lessor.

Concerning records kept on the maintenance of motor cars, 12 of the reporting railroads keep various records of operation and maintenance; four roads keep complete records on motor cars; four roads maintain records of maintenance only; one road has records of fuel consumption only; and three railroads maintain records of general repairs only. Seventeen roads do not keep any record of operation or maintenance.

In general, the reporting roads advise that the replacement of any truck is determined by a field inspection, taking into consideration the mileage, type of use, general condition, cost of necessary repairs, and requirement for the truck.

One road advises specifically that it has set up a 5-year cycle for replacement of all its trucks. Another road advises that its panel and pick-up trucks average 15,000 miles annually, stake body trucks, 10,000 miles, and dump trucks, 7000 miles, and the general practice has been to replace them in 6 years. One road advises it replaces trucks when the estimated cost of the general overhaul of one approximates 75 percent of its book value.

6. Economy Derived

The railroads which have kept actual records advise that it costs from 8 to 15 cents per mile to operate a truck, depending on make and type, and including interest, depreciation, repairs and supplies, whereas motor car operation costs about one-third this amount. The percentage earned annually is reported as ranging from 20 percent to 100 percent. The savings per truck per year vary with the class of gang using the truck. Savings on small pick-up trucks have been reported at $700 annually, while the savings on 2-ton trucks serving district and extra track gangs, bridge and structure and signal gangs amount to $3000 annually. The savings on specially equipped trucks are reported as 50 percent on the investment.

It should be considered that the lengthening of sections and the introduction of district gangs has presented a problem in obtaining the maximum number of productive hours on the job. A partial solution has been brought about through the use of trucks in reducing the unproductive hours resulting from the operation of motor cars, particularly on single track. During the past few years, the speed of both freight and passenger trains has been increased, which results in still additional time lost through the use of motor cars in starting for work in the morning or leaving for headquarters at night, because of waiting for trains, clearance orders, lineups or for yard congestion to clear up. Most railroads reported from one to two gang hours saved per truck per day. This saving in time, when figured for the larger gangs, such as bridge and structure, signal, communications department, district and extra track gangs, results in distinct economy.

Some railroads reported that they have eliminated complete track, carpenter and signal camps, and also individual camp cars, thus saving the high cost of maintaining camp cars and equipment. There were also reports from some railroads of decrease in the number of work trains through the use of trucks.

There is no doubt that unseen economies result through the use of trucks in lieu of motor cars in cases of emergencies, such as derailments and washouts, in quickly assembling men and material at the site of the trouble, and thus restoring the railroad more quickly to operation.

Motor car accidents involving trains are eliminated. This results in saving the costs of damage to motor cars and the costs resulting from death or injury to railroad employees. This is partially off set by a certain element of hazard that exists in truck operation over highways.

7. Advantages and Disadvantages of Truck Operation

Advantages

(a) Eliminates unproductive hours resulting from delays to motor cars by operation of trains.
(b) Makes it possible to concentrate a larger number of men, tools and material within a shorter period of time than with motor cars.
(c) Saves man-hours going to and from work because of the higher safe speed of truck over that of motor car.
(d) Permits recruiting of labor at outlying points.
(e) Eliminates motor car accidents and personal injuries resulting from such accidents.
(f) Provides an eating place and shelter for employees during inclement weather.
(g) Allows elimination of camp cars.
(h) Speeds up deliveries of material for work under way, thus increasing the progress.

(i) Affords distribution of material, supplies and fuel for equipment direct to site of work, reducing work trains and second handling.

(j) Trucks are efficient in the winter in eliminating the rehandling of snow and in the delivery of men, tools and supplies.

(k) Facilitate repairs to crossings, driveways, crossing gates and flashers, increasing the output of men doing this work as much as 25 to 50 percent.

Disadvantages

(a) Greater initial cost of trucks.
(b) Greater cost of operation and maintenance.
(c) Highway is not always accessible to the work site.
(d) Inability of foreman and others to observe track, other facilities and conditions which require attention.
(e) Increases public liability hazard.

CONCLUSIONS

The use of trucks in lieu of motor cars has resulted in substantial savings in various phases of maintenance of way work, where the geographical location and traffic of the railroads warrant their use. The savings are realized principally from the reduction of unproductive work hours resulting from motor car operation, the elimination of camps and equipment, and reduction in the cost of handling material to job sites.

These economies can be obtained after a well thought out plan of organization and operation, giving careful study to each phase of maintenance work and location involved. Where main or branch line traffic is heavy and highways or secondary roads are fairly close to the railroads, trucks should be used in lieu of motor cars. The same holds true in and around terminals where railroad traffic congestion results in frequent and long delays to workmen and in the handling of material by motor car.

It is difficult to evaluate exactly in dollars and cents the actual economies effected by the railroads which have replaced all or part of their motor cars by trucks, because in recent years the 40-hr week has gone into effect, forces have been reduced as the result of general economic conditions, and there has been a large increase in labor rates. However, the state of maintenance of the railroads in general continues to improve. This improvement is partially due to improved and heavier material, but is principally due to improved methods and planning. It is felt that the substantial reduction in man-hours is in great measure due to the increased use of trucks in place of motor cars.

Report on Assignment 8

Economic Size of Maintenance Force Using On or Off-Track Tampers and Renewing an Average of 100 Ties per Mile

P. A. Cosgrove (chairman, subcommittee), A. D. Alderson, H. C. Archibald, W. H. Brameld, E. J. Brown, G. E. Chambers, M. H. Dick, W. W. Edwards, W. H. Freeman, L. C. Gilbert, W. H. Hamilton, K. H Hanger, E. B. Harris, G. W. Hunt, W. I. King, L. A. Loggins, W. H. Miesse, H. C. Minteer, J. A. Pollard, W. R. Rees, M. S. Reid, J. S. Snyder, F. R. Spofford, W. H. Vance, H. J. Weccheider, H. E. Wilson, H. M. Williamson.

Your committee submits the following report as information.

Questionnaires were sent to 40 railroads requesting that they furnish information as to the method used, and the number of man-hours and cost per mile to perform out-of-face surfacing operations; also the method used and the cost of installing cross ties.

Replies were received from 23 railroads, reporting a total of 67 surfacing operations and indicating that 4 types of on-track tampers and 2 types of off-track tampers are predominant in carrying out this work.

In general, both types of tamper operations used 1 foreman with gangs of 8 to 20 men. One foreman and 1 assistant foreman were used with gangs of 20 to 40 men. One foreman and 2 assistant foremen were used with gangs of 40 to 65 men.

One machine operator was used with 24 on-track surfacing operations, and 2 machine operators were used with 6 on-track surfacing operations, indicating that one relief operator was used in order to operate the tampers continuously.

The fuel and maintenance expenses shown indicate running expenses and road repairs, but do not include the general overhaul of equipment at the end of a season's work.

Pilot service for on-track tampers was used on 8 surfacing operations.

Listed below are the average labor expenses per mile involved in out-of-face surfacing operations by on-track and off-track tampers, as furnished by all of the reporting railroads:

	On-Track Tampers		*Off-Track Tampers*	
Dig jack holes	$ 32.34		$ 34.00	
Handle jacks	81.82		115.16	
Spacing ties	61.24		182.10	
Handling ballast	169.46		191.37	
Tamping track	93.73		391.35	
Adjust anchors	28.77		24.53	
Line track	129.98		77.17	
Miscellaneous	105.35		108.93	
Delays	212.38		133.31	
Total laborers—surfacing and lining		$ 915.07		$1,257.92
Foremen	59.96		75.93	
Asst. foremen	49.78		None	
Machine operators	42.58		None	
Pilot service	33.76		None	
Machine fuel and maintenance	38.63		20.97	
Total—Foremen, machine operators, etc.		24.71		96.90
Total cost per mile		$1,139.78		$1,354.82

The foregoing figures do not include the distribution of new ties or the renewal or disposal of old ties. Handling ballast means handling by forks, shovels, etc., at the time of operation. The average raise was 1½ in.

An important item of labor expense involved is the traffic delays. Delays due to traffic varied from a minimum of 1 percent to a maximum of 50 percent of the total labor used in the surfacing operation. Those railroads fortunate enough to obtain track occupancy by detouring traffic around the gangs, or by fleeting the freight trains, showed the most economical operation of on-track tamping machines.

The reporting railroads indicated that on 41 surfacing operations they felt justified in using on-track tampers, but that on 26 surfacing operations traffic was of such density that off-track tampers proved more economical.

The cost per mile of labor worked with on-track tampers varied from a low of $225 per mile using an 8-man gang where no traffic delays were shown, to a high of $2887 per mile using a 65-man gang where traffic delays amounted to 32.6 percent of the total labor.

The average labor cost of out-of-face surfacing, using on-track tampers, was $915 per mile, and the average delays amounted to $212.38, or 18.6 percent of the total cost. The cost of pilot service, machine operators, fuel and equipment maintenance averaged $115 per mile.

The cost per mile of labor worked with off-track tamping machines varied from a low of $1120 per mile for a 24-man gang, to a high of $3401 per mile for a 63-man gang, and averaged $1258. Fuel and maintenance costs for off-track tamping machines averaged $21.00 per mile. No pilot service or machine operators were used.

In seventeen of the surfacing operations reported, cross ties were dug in ahead of the surfacing by section men.

In five of the surfacing operations reported, a mechanized tie gang was used ahead of the surfacing operation.

In sixteen surfacing operations reported, cross ties were installed in connection with the surfacing operation.

CONCLUSION

In general it was found that if the surfacing operation is given sufficient track occupancy by use of the detour method or the fleeting of freight trains, so the expense of traffic delays is a small percent of the total labor, it is more economical to use on-track equipment.

If the expense of traffic delays amounts to a large portion of the total labor used for the surfacing operation, it is more economical to use hand-held, off-track equipment.

The most economical size gangs performing an out-of-face surfacing operation, using either on-track or off-track equipment, did not install cross ties during the surfacing operation. The ties were applied as a separate project either by digging in by hand or by a mechanized tie gang prior to the surfacing operation.

The small gangs of 24 men or less performed the most economical work when using either the on-track or off-track equipment. However, it is found necessary for many railroads to sacrifice some economy in order to perform the work faster because of short working seasons or other time limits that affect the surfacing programs.

Report of Committee 30—Impact and Bridge Stresses

E. S. Birkenwald,
Chairman,

M. J. Plumb,
Vice Chairman,

E. R. Andrlik
D. S. Bechly
J. H. Brown
E. E. Burch
A. B. Chapman
Abram Clark
F. H. Cramer
C. P. Cummins
A. C. Danks, Jr.
J. A. Erskine
A. T. Granger
A. R. Harris
R. H. Heinlen
C. S. Johnson
W. B. Kuersteiner
C. T. G. Looney
C. V. Lund
J. F. Marsh
James Michalos
W. H. Munse
D. W. Musser
C. H. Newlin
N. M. Newmark
E. W. Prentiss
H. C. Prince
C. A. Roberts
J. H. Shieber
C. E. Sloan
C. B. Smith
R. L. Stevens
E. Wollett, Jr.
W. M. Wilson (E)
J. D. Woodward
L. T. Wyly

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Viaduct columns, collaborating with Committee 15.

   No report.

2. Steel girder spans with open decks and with ballasted decks.

   Progress report, presented as information ..... page 434

3. Dynamic shear in girder and truss spans.

   Progress report, presented as information ..... page 434

4. Impact and bending stresses in columns and hangers of truss spans.

   No report.

5. Concrete structures, collaborating with Committee 8.

   Progress report, presented as information ..... page 434

6. Determination of braking and traction forces in bridge structures, collaborating with Committees 7, 8 and 15.

   No report.

7. Stresses and impacts in timber stringer bridges, collaborating with Committee 7.

   Progress report, presented as information ..... page 435

8. Steel truss spans with open decks and with ballasted decks

   Progress report, presented as information ..... page 435

9. Distribution of live load in bridge floors:
   (a) floors consisting of transverse beams;
   (b) floors consisting of longitudinal beams.

   No report.

10. Stresses in lateral bracing of bridges.

    Progress report, presented as information ..... page 435

THE COMMITTEE ON IMPACT AND BRIDGE STRESSES,
E. S. BIRKENWALD, *Chairman.*

AREA Bulletin 526, December 1955.

Report on Assignment 2

Steel Girder Spans with Open Decks and with Ballasted Decks

M. J. Plumb (chairman, subcommittee), E. R. Andrlik, D. S. Bechly, E. E. Burch, F. H. Cramer, C. P. Cummins, A. C. Danks, Jr., A. T. Granger, A. R. Harris, C. T. G. Looney, J. F. Marsh, James Michalos, W. H. Munse, D. W. Musser, N. M. Newmark, H. C. Prince, C. E. Sloan, C. B. Smith, J. D. Woodward.

A report of tests on 10 plate-girder spans on the Chicago Milwaukee, St. Paul and Pacific Railroad was published in AREA Bulletin 523, June–July 1955, page 15. This report covered the stresses in the flanges, webs and bracing produced by the passage of high-speed diesel and steam locomotives.

A report of tests on 5 plate-girder spans on the Atchison, Topeka and Santa Fe Railway will be approved for publication this year. Progress is reported in the analysis of data obtained during tests on 10 plate-girder spans on the Chicago, Burlington and Quincy Railroad. Report on the Burlington tests is scheduled for completion in 1956.

Report on Assignment 3

Dynamic Shear in Girder and Truss Spans

(For subcommittee, see report on Assignment 2)

A report on this assignment is included in the report of tests on 10 plate-girder spans on the Milwaukee Road, referred to in Assignment 2.

Report on Assignment 5

Concrete Structures

Collaborating with Committee 8

J. H. Shieber (chairman, subcommittee), Abram Clark, J. A. Erskine, R. H. Heinlen, James Michalos, E. W. Prentiss, C. A. Roberts.

The research staff of the Association of American Railroad is now analyzing the data obtained during the full-size tests conducted on six reinforced concrete bridge slabs in the laboratory of the U. S. Bureau of Reclamation at Denver, Colo. The strains on the concrete slabs and the cylinders have all been reduced from the oscillograms into tabular form, and the remaining work consists mainly of preparing diagrams showing

these strains in a manner similar to that used for the tests on reinforced concrete pipe, reported on in the 1955 Proceedings.

As a result of the successful behavior of the prestressed slab under static load, two additional prestressed slabs, manufactured at the same time, were placed in a Burlington Railroad bridge near Hunnewell, Mo. These are the first prestressed, pretensioned railroad slabs to be installed in this country. Field tests under actual operating conditions were conducted during October 1955 by the research staff of the Association of American Railroads to determine the stresses and impacts in these slabs. In addition to these tests, similar data were obtained on adjoining concrete slabs designed by the conventional theory.

A final report will be issued after all of the data taken at Denver and in the field have been analyzed.

Report on Assignment 7

Stresses and Impacts in Timber Stringer Bridges

Collaborating with Committee 7

C. V. Lund (chairman, subcommittee), J. H. Brown, A. B. Chapman, C. S. Johnson, C. H. Newlin, R. L. Stevens, E. Wollett, Jr.

Tests were conducted on two ballasted-deck pile trestles on the Seaboard Air Line Railroad during the latter part of 1954 and early 1955. These are the first in a series of tests to be conducted on timber trestles.

In the tests strains were measured in the stringers and piles of both trestles under regularly operated trains over a wide range of speed. The data will be analyzed to determine the magnitude and duration of time of the strains, and the frequency of occurrence of maximum strains in order to correlate the data with the basic strength of the timber.

The tests included measurements to determine the magnitude of longitudinal forces resisted by the piles, rails and the embankment behind the dump bents.

Report on Assignment 8

Steel Truss Spans with Open Decks and with Ballasted Decks

(For subcommittee, see report on Assignment 2)

A report will be published this year covering a method of calculating the effect of gusset plates in the analysis of trusses as rigid frames.

Tests were made during 1955 on a bascule bridge in Cleveland, Ohio, at the request and expense of the River Terminal Railway, to determine if the bridge could safely carry heavily loaded steel ladle cars.

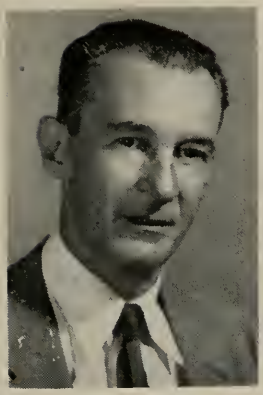
Report on Assignment 10

Stresses in Lateral Bracing of Bridges

(For subcommittee, see report on Assignment 2)

A report on this assignment is included in the report of tests on the 10 plate-girder spans on the Milwaukee Road referred to in Assignment 2.

Report of Committee 29—Waterproofing



HENRY SEITZ, *Chairman,*

E. A. JOHNSON,
Vice Chairman,

W. H. ACKER, JR.
A. L. BECKER
D. E. BRAY
LYLE BRISTOW
R. J. BRUESKE
M. W. BRUNS
W. H. BUNGE
A. E. CAWOOD
R. A. M. DEAL
O. E. FORT
E. T. FRANZEN
NELSON HANDSAKER
W. G. HARDING
E. KIMMEL
J. A. LAHMER (E)
R. L. MAYS
L. H. NEEDHAM
B. J. ORNBURN
H. A. PASMAN
MILTON PIKARSKY
R. D. POWRIE
W. E. ROBEY
F. S. SCHUBERT
R. I. SIMKINS
T. M. VON SPRECKEN
C. A. WHIPPLE (E)
K. B. WOODS

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects.

1. Revision of Manual.

   Progress in study but no report.

2. Waterproofing materials and their application to railway structures, collaborating with Committees 6, 8 and 15.

   Progress report, presented as information ..... page 438

3. Waterproofing coatings to prevent concrete deterioration, collaborating with Committees 6 and 8.

   Final report ..... page 439

THE COMMITTEE ON WATERPROOFING,
HENRY SEITZ, *Chairman.*

AREA Bulletin 526, December 1955.

Report on Assignment 2

Waterproofing Materials and Their Application to Railway Structures

Collaborating with Committees 6, 8 and 15

R. J. Brueske (chairman, subcommittee), A. L. Becker, D. E. Bray, W. H. Bunge, A. E. Cawood, E. T. Franzen, B. J. Ornburn, Milton Pikarsky.

Your committee presents the following progress report, which is submitted as information. The report is descriptive in nature, and it is the intent to familiarize readers with the progress to date on the study and investigation being made on bituminous waterproofing materials and membranes.

WATERPROOFING MATERIALS

In developing the general revisions to Chapter 29 of the Manual, which were approved at the 1953 convention, the committee realized that additional research on waterproofing materials was necessary. Recommendation was made to test the asphalts and coal tars as generally produced by the manufacturers to meet the specifications of the AREA and ASTM, to determine their relative merits. This research was carried out at Purdue University under the general supervision of the research staff of the Association of American Railroads at the request of your committee.

A total of 45 specification grade waterproofing bitumens and 30 proprietary coatings were collected for study of their waterproofing characteristics. The specification grade materials conformed with the former AREA specification for asphalt and the current ASTM specifications for asphalts and coal tar pitch.

The proprietary coatings consisted of asphaltic cut backs with asbestos fiber or mineral fiber, asphalt and coal tar emulsions, and specially refined asphalt cements. Materials were tested under long time immersions, by exposure to carbon-arc light and water spray, by outdoor weathering, for the effect of alkali soil conditions, and for low temperature ductility.

The work involving the above materials has been completed and a report is being edited by your committee. The report will be presented in an early issue of the AREA Bulletin.

Conclusions reached from these tests confirm the revisions recently made and incorporated in the current waterproofing specifications. Your committee is satisfied that the basic asphalt materials as now specified provide good materials readily obtainable from various manufacturers.

Investigation of coal tar pitch is being progressed, and it is expected that the specification for this material will be revised in the near future. Study is also being made to modernize several of the testing methods now specified for materials.

WATERPROOFING MEMBRANE

The AAR research staff is testing waterproofing membranes at the Chicago research center. Progress on these tests is necessarily slow since considerable exploratory work has been required to develop suitable testing apparatus.

The program presently outlined is to observe the reaction of membrane waterproofing under conditions simulating its actual service. Many variable factors, such as

the type of material, stretch, temperature changes, action under hydraulic head, and the number of plies of material, are being considered.

Your committee feels confident that the data obtained from these investigations will ultimately lead to an improved specification.

Report on Assignment 3

Waterproofing Coatings to Prevent Concrete Deterioration

Collaborating with Committees 6 and 8

F. S. Schubert (chairman, subcommittee), Lyle Bristow, O. E. Fort, W. G. Harding, E. A. Johnson, Earl Kimmel, L. H. Needham, W. E. Robey, R. I. Simkins, K. B. Woods.

After considerable research and study, specifications for waterproofing coatings for exposed concrete surfaces were prepared under this assignment and adopted in 1953. Your committee, therefore, considers this assignment complete.

Report of Committee 3—Ties

L. C. Collister, *Chairman*

L. P. Drew,
Vice Chairman,

J. E. Armstrong, Jr.
P. D. Brentlinger
C. S. Burt
W. J. Burton
G. B. Campbell
C. M. Coates
E. L. Collette
B. S. Converse
R. L. Cook
R. W. Cook
B. E. Crumpler
H. R. Duncan
A. K. Frost
F. J. Fudge
W. E. Fuhr
R. F. Garner
L. E. Gingerich
J. D. Hadley
C. L. Heimbach
F. F. Hornig
B. D. Howe
M. J. Hubbard
R. P. Hughes
C. E. Jackman
W. R. Jacobson
G. R. Janosko
H. W. Jensen
W. L. Kahler
L. W. Kistler
C. M. Long
Roy Lumpkin
T. O. Manion
W. G. Park
R. H. Paschal
F. A. Poling
Arthur Price
W. C. Reichow
N. B. Roberts
H. S. Ross
N. A. Salzano
C. V. Schuti
E. F. Snyder
S. Thorvaldson
G. A. Williams
R. G. Wintrich
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress in study but no report.

2. Extent of adherence to specifications.

   No report.

3. Substitutes for wood ties

   Oral report to be made at annual meeting.

4. Tie renewals and costs per mile of maintained track.

   The report on this assignment, consisting of the annual statistics compiled by the Bureau of Railway Economics, AAR, and providing information about tie renewals and cost data for 1954, was published in Bulletin 523, June–July 1955.

5. Methods of retarding the splitting and the mechanical wear of ties, including stabilization of wood, collaborating with Committee 5, and NLMA.

   Oral report to be made at annual meeting.

6. Bituminous coating of ties for protection from the elements.

   Progress in study but no report.

7. Causes leading to the removal of ties.

   Progress in study but no report.

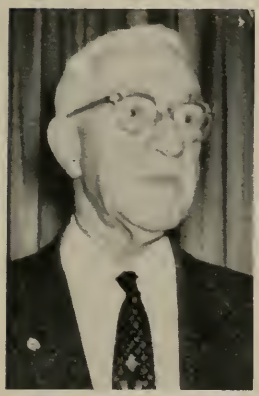
8. End splitting of cross and switch ties.

   Progress in study but no report.

The Committee on Ties,
L. C. Collister, *Chairman.*

AREA Bulletin 526, December 1955.

Report of Committee 17—Wood Preservation



A. J. Loom, *Chairman*
W. C. Reichow,
Vice Chairman,

A. B. Baker
W. W. Barger
J. A. Barnes
A. S. Barr
R. S. Belcher (E)
P. D. Brentlinger
Walter Buehler (E)
C. M. Burpee
C. S. Burt
G. L. Cain
G. B. Campbell
H. B. Carpenter
L. C. Collister
G. H. Dayett, Jr.
R. F. Dreitzler
H. R. Duncan
T. H. Friedlin
F. J. Fudge
W. H. Fulweiler
R. R. Gunderson
H. M. Harlow
W. H. Hillis, Jr.
B. D. Howe
M. S. Hudson
R. P. Hughes
H. E. Hurst
M. F. Jaeger
W. L. Kahler
T. D. Kern
L. W. Kistler
J. W. McGlothlin
G. L. P. Plow
R. R. Poux
M. H. Priddy
R. B. Radkey
A. P. Richards
B. J. Richards
H. M. Shudlich
W. B. Stombock
F. H. Taylor
H. C. Todd
C. H. Wakefield
Committee

(E) Member Emeritus.

To the American Railway Engineering Association

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, submitting Manual recommendations ..... page 444

2. Service test records of treated wood
   Results of service tests, submitted as information ..... page 446

3. Destruction by marine organisms; methods of prevention
   Results of service tests, submitted as information ..... page 457

4. Petroleum as a carrier or extender of creosote or pentachlorophenol.
   Progress in study but no report.

5. Destruction by termites; methods of prevention, collaborating with Committees 6 and 7.
   Initial report on installation of a new test plot at University of Florida .. page 464

6. New impregnants and procedures for increasing the life and serviceability of forest products.
   Presents for adoption a specification for chromated zinc arsenate ..... page 464

7. Incising forest products.
   Progress in study but no report.

8. Effect on AREA standards and specifications of any changes in manufacturing processes and specifications for creosote, petroleum and other products.

Progress report, submitting for adoption a table showing volume correction factors for preservative salt solutions ..... page 465

9. Treatment of wood to make it fire resistant, collaborating with Committees 6 and 7.

The committee submits a specification for adoption ..... page 468

10. Artificial seasoning of forest products prior to treatment.

Progress in study but no report.

12. Treatment of laminated timbers, collaborating with Committee 7.

Brief progress report ..... page ...

THE COMMITTEE ON WOOD PRESERVATION,
A. J. LOOM, *Chairman.*

AREA Bulletin 526, December 1955.

Report on Assignment 1

Revision of Manual

C. S. Burt (chairman, subcommittee), Walter Buehler, C. M. Burpee, G. B. Campbell, H. R. Duncan.

In its report last year (Proceedings, Vol. 56, 1955, page 490) your committee presented as information a number of revisions of material in Chapter 17 of the Manual to bring it up to date with respect to methods and practices of the industry. Your committee now recommends that certain of these revisions be adopted. Its specific recommendation are as follows:

Page 17–1–3

PRESERVATIVES

Reapprove with the following revision:

In the third paragraph delete the words "Zinc Chloride". This is recommended because less than 5 percent of the zinc-chloride-containing preservatives being used today is straight zinc chloride.

Page 17–2–1

CREOSOTE

Reapprove with the following revision:

Make editorial changes in the wording of Note 1 to clarify the now rather complex wording, and show some of the information in the note in tabular form.

Note 1 now reads, "Samples of used creosote may show increases in matter insoluble in benzol and in coke residue, and decreases in percentages of distillate, due to treating operations. If neither the matter insoluble in benzol nor the coke residue exceeds the specification limits by more than 1 percent, and if the percentages of distillate are not lower than the specification minimum limits by more than 3 percent, and it can be

shown that the original creosote was of specified quality, the used creosote shall be regarded as conforming to the specification".

Proposed revision—"Due to treating operations, samples of used creosote may show increases in matter insoluble in benzol, and in coke residue, and decreases in percentage of distillate up to 235 deg C. If it can be shown that the original creosote was of the specified quality, and the used creosote conforms to the standard requirements with the following exceptions:

Benzol insoluble matter, max, percent	1.5
Coke residue, max, percent	3.0
Distillate up to 235 deg C, min, percent	2

it shall be considered as conforming."

Page 17–2–2

CREOSOTE–COAL TAR SOLUTION

Reapprove with the following revision:

Make editorial changes in the wording of Note 1 for the purpose of clarification, and show some of the information in the note in tabular form.

Note 1 now reads, "Samples of used creosote–coal tar solutions may show increases in matter insoluble in benzol and coke residue as a result of treating operations. Such increases, provided they do not exceed by 1 percent the specification limits, should not cause rejection of the solution if it can be shown that the original fresh solution was of specified quality."

Proposed wording—"Due to treating operations, samples of used creosote–coal tar solutions may show increases in matter insoluble in benzol and in coke residue. If it can be shown that the original solution was of the specified quality, and the used solution conforms to the standard requirements with the following exceptions:

	Grade A	*Grade B*	*Grade C*	*Grade D*
Benzol insoluble matter, max, percent	3.0	4.0	4.5	5.0
Coke residue, max, percent	6.0	8.0	10.0	12.0

it shall be considered as conforming".

Page 14–4–1 to
17–4–18, incl.

SPECIFICATIONS FOR TREATMENT

Reapprove with the following revisions:

Add to the sixth paragraph of Art. 2, Sec. A, (third paragraph on page 17–4–2), the following sentences: "Ice-coated or frozen material may be steamed prior to conditioning or treatment for a total period not to exceed 2 hr. The temperature shall not exceed 240 deg F."

On page 17–4–5—Combine paragraphs 2 and 3 of Art. 1, Sec. C, and change to read as follows: "The retention of oil-borne and water-borne preservatives shall be expressed in pounds of dry preservative per cubic foot. The volume and specific gravity correction tables of the AREA shall be used in calculating retention."

On page 17–4–10—At the top of the table on this page delete the heading "Posts" and substitute therefor the heading "Lumber, Timbers and Bridge Ties, Cont'd.", to correct an inadvertent transposition of headings in the printing of this page and page 17–4–15 in 1954.

On page 17–4–15—At the top of the table on this page delete the heading "Lumber, Timbers, and Bridge Ties, Cont'd." and substitute therefor the heading "Posts", to correct an inadvertent transposition of headings in the printing of this page and page 17–4–10 in 1954.

In addition, your committee presents, as information, the following proposed changes in Manual material which will be given careful study during the coming year.

METHOD OF SAMPLING CREOSOTE IN TANK CARS

This recommended procedure as it now appears in the Manual was reapproved without change in 1953. However, the committee believes that the whole procedure as now described needs careful study to determine what revisions are required in order that the Manual may conform to improved practices in this regard.

FLASH POINT OF PETROLEUM

This is a question that has come before this committee many times during the past few years. It is our information that some associations have recently seen fit to reduce the flash point of preservative used as a diluent for creosote from 215 deg F to 175 deg F. We feel that study of the question should be made, looking to recommendations with respect to any action that should be taken by the Association.

FLASH POINT OF CREOSOTE

AREA specifications do not now make any reference whatever to the flash point of creosote. There is a feeling among some of our members that this is a question which should receive special attention and study with the view toward a recommendation as to whether such a limit should be set in AREA specifications.

STRENGTH REQUIREMENT OF PENTACHLOROPHENOL SOLUTION

At the present time AREA specifications do not include requirement for the strength of penta solution. It is our advice that some associations have recently adopted as standard a statement that the penta treating solution shall contain from 4.5 percent to 5.5 percent, by weight, of pentachlorophenol.

It is our thought that this question should be progressed to a decision as to whether a similar statement should be included in AREA specifications.

TREATMENT OF CAR MATERIALS

Presently our Manual includes no reference whatever to the treatment of these extremely important items. It is the thinking of your committee that this is a field to which very special attention and follow-up should be given. Accordingly, it is proposed to consider whether the necessary specifications should be developed.

Report on Assignment 2

Service Test Records of Treated Wood

R. P. Hughes (chairman, subcommittee), G. H. Dayett, Jr., W. H. Hillis, Jr., T. D. Kern, L. W. Kistler, G. L. P. Plow, R. R. Poux, R. B. Radkey, W. C. Reichow, W. B. Stombock, F. H. Taylor.

Your committee submits the following progress reports on service tests of treated wood.

Chicago, Rock Island and Pacific report on 1955 inspections of cross tie test sections in Iowa, Nebraska, Kansas, Missouri, Texas and Arkansas.

Union Pacific report on 1955 inspections of cross tie test sections at various locations.

Illinois Central report on 1955 inspection of cross tie test section at Canton, Miss.

St. Louis–San Francisco report on service records of treated wood in bridges on its Western Division between Tulsa, Okla., and Enid.

CHICAGO, ROCK ISLAND & PACIFIC RAILROAD SERVICE RECORDS OF TREATED TIES—1955

Reuping Treatment

Kind of Tie	Reuping Treatment	Year Inserted	Original Number Inserted	Ties Removed		Ties Remaining in Track	Avg. Life of Ties to Date
				Total	Percent		
Red Oak	Ola	1908	28	28	100	0	15.28
Gum	McLean	1908	264	264	100	0	22.61
Elm	McLean	1908	27	27	100	0	24.11
Pine	Ola	1908	38	38	100	0	18.34
Pine	McLean	1908	1819	1819	100	0	20.99
Pine	Chico	1908	690	653	95	37	18.98
Red Oak	Ola	1909	728	728	100	0	19.83
Red Oak	Yukon	1909	649	646	99	3	17.37
Gum	Leola	1909	385	376	98	9	16.82
Gum	Ola	1909	80	80	100	0	18.86
Gum	Yukon	1909	546	526	96	20	23.35
Gum	Okarche	1909	71	62	87	9	24.35
Pine	Leola	1909	1394	1394	100	0	16.10
Pine	Ola	1909	1012	1008	99	4	17.70
Pine	Yukon	1909	1586	1585	99	1	14.98
Pine	Okarche	1909	380	377	99	3	17.19
Pine	Chico	1909	2324	2251	97	73	19.90
Red Oak	Topeka	1910	1227	1207	98	20	29.16
Red Oak	Ola	1910	68	68	100	0	17.66
Gum	Leola	1910	80	80	100	0-	14.23
Gum	Okarche	1910	73	59	81	14	24.32
Pine	Topeka	1910	501	474	95	27	21.11
Pine	Leola	1910	1861	1860	99	1	14.36
Pine	Ola	1910	430	428	99	2	16.14
Pine	Yukon	1910	1003	990	98	13	17.06
Pine	Okarche	1910	749	718	96	31	22.23
Red Oak	Topeka	1911	864	863	99	1	19.62
Red Oak	Ola	1911	42	42	100	0	18.31
Red Oak	Yukon	1911	416	410	99	6	14.76
Red Oak	McLean	1911	517	517	100	0	25.58
Red Oak	Okarche	1911	149	144	97	5	21.99
Gum	Ola	1911	66	66	100	0	20.27
Gum	Okarche	1911	146	114	78	32	23.23
Pine	Topeka	1911	180	176	98	4	21.95
Pine	Leola	1911	277	276	99	1	15.00
Pine	Ola	1911	5031	5007	99	24	16.85
Pine	Yukon	1911	1406	1406	100	0	15.65
Pine	McLean	1911	11	9	82	2	18.77
Pine	Okarche	1911	977	949	97	28	19.92
Pine	Chico	1911	2020	1904	94	116	22.24
Red Oak	Yukon	1912	373	371	99	2	15.23
Red Oak	McLean	1912	152	152	100	0	20.40
Gum	Okarche	1912	203	151	74	52	24.51
Pine	Dalhart	1912	566	532	94	34	22.36
Pine	Leola	1912	1761	1748	99	13	14.97
Pine	Ola	1912	614	613	99	1	15.79
Pine	Yukon	1912	1579	1558	99	21	15.00
Pine	Okarche	1912	1426	1321	93	105	20.04
Pine	Chico	1912	870	858	99	12	20.71
Red Oak	Yukon	1913	443	442	99	1	15.84
Red Oak	Okarche	1913	175	160	91	15	21.21
Pine	Dalhart	1913	1115	1020	91	95	23.06
Pine	Leola	1913	1714	1692	99	22	17.25
Pine	Yukon	1913	1863	1747	94	116	17.96
Pine	Okarche	1913	763	690	90	73	22.96
Pine	Chico	1913	1061	1044	98	17	20.10
Red Oak	Ola	1914	266	258	97	8	22.54
Gum	Yukon	1914	296	272	92	24	25.72
Pine	Ola	1914	89	89	100	0	16.82
Pine	Yukon	1914	1888	1871	99	17	17.66
Pine	Okarche	1914	1516	1363	90	153	21.29
Pine	Chico	1914	655	615	94	40	19.24

CHICAGO, ROCK ISLAND & PACIFIC RAILROAD

SERVICE RECORDS OF TREATED TIES—1955 Sheet 1 of 2 sheets

Lowry Treatment

Kind of Ties	Lowry Treatment	Year Inserted	Original Number Inserted	Ties Removed Total	Ties Removed Percent	Ties Remaining in Track	Avg. Life of Ties to Date
Red Oak	Clarksville	1907	345	345	100	0	27.88
Gum	Clarksville	1907	99	94	95	5	24.83
Red Oak	Tiskilwa	1908	514	514	100	0	20.54
Red Oak	Altoona	1908	477	456	96	21	28.24
Red Oak	Ely	1908	1178	1174	99	4	24.17
Red Oak	Clarksville	1908	1641	1618	99	23	25.07
Red Oak	West Bend	1908	149	143	96	6	28.31
Red Oak	Fairbury	1908	502	502	100	0	29.15
Red Oak	Goodland	1908	87	87	100	0	33.48
Gum	Tiskilwa	1908	71	66	93	5	16.80
Gum	E. Des Moines	1908	99	96	97	3	25.83
Gum	Ely	1908	391	391	100	0	21.30
Gum	Clarksville	1908	95	95	100	0	24.74
Gum	West Bend	1908	887	839	95	48	30.64
Gum	Fairbury	1908	114	114	100	0	22.97
Pine	Dalhart	1908	306	300	98	6	30.38
Elm	Tiskilwa	1908	38	38	100	0	16.87
Elm	Clarksville	1908	103	103	100	0	24.47
Elm	West Bend	1908	238	231	97	7	29.28
Maple	West Bend	1908	7	7	100	0	39.57
Red Oak	Tiskilwa	1909	1326	1326	100	0	22.71
Red Oak	Altoona	1909	1445	1445	100	0	29.12
Red Oak	Ely	1909	971	937	96	34	25.07
Red Oak	Clarksville	1909	1590	1567	99	23	26.62
Red Oak	Fairbury	1909	321	321	100	0	28.52
Red Oak	Goodland	1909	1118	1118	100	0	32.26
Red Oak	Topeka	1909	891	882	99	9	21.80
Gum	Tiskilwa	1909	58	47	81	11	22.40
Gum	Altoona	1909	63	10	16	53	25.30
Gum	E. Des Moines	1909	596	584	98	12	21.67
Gum	Ely	1909	126	126	100	0	22.33
Gum	West Bend	1909	539	496	92	43	31.46
Gum	Dalhart	1909	894	803	90	91	28.70
Pine	E. Des Moines	1909	378	378	100	0	22.82
Pine	Ely	1909	214	206	96	8	25.71
Pine	Goodland	1909	136	124	91	12	29.74
Pine	Dalhart	1909	165	155	94	10	28.36
Elm	E. Des Moines	1909	186	182	98	4	22.47
Elm	West Bend	1909	16	9	56	7	34.11
Elm	Dalhart	1909	49	40	82	9	29.30
Maple	West Bend	1909	11	4	36	7	32.00
Red Oak	Tiskilwa	1910	2838	2780	98	58	25.10
Red Oak	Altoona	1910	583	576	99	7	32.25
Red Oak	Ely	1910	2343	2343	100	0	25.94
Red Oak	Clarksville	1910	1473	1459	99	14	27.53
Red Oak	Fairbury	1910	1721	1721	100	0	28.42
Red Oak	Eldon	1910	4129	4071	99	58	27.24
Red Oak	Topeka	1910	443	443	100	0	20.85
Gum	Tiskilwa	1910	55	52	95	3	24.29
Gum	E. Des Moines	1910	309	284	92	25	19.96
Gum	Ely	1910	159	159	100	0	22.62
Gum	West Bend	1910	279	260	93	19	32.05
Pine	E. Des Moines	1910	155	154	99	1	25.63
Pine	Ely	1910	108	107	99	1	24.27
Pine	West Bend	1910	57	57	100	0	35.16
Pine	Fairbury	1910	231	231	100	0	29.38
Pine	Goodland	1910	727	718	99	9	30.97
Pine	Topeka	1910	261	261	100	0	21.46
Elm	Tiskilwa	1910	8	8	100	0	16.50
Elm	West Bend	1910	41	30	73	11	30.53
Red Oak	Tiskilwa	1911	1099	1064	97	35	23.07
Red Oak	Ely	1911	2256	2220	99	36	27.22
Red Oak	Altoona	1911	763	757	99	6	31.15
Red Oak	West Bend	1911	89	79	89	10	32.57
Red Oak	Fairbury	1911	51	51	100	0	28.51
Red Oak	Goodland	1911	105	105	100	0	31.36

CHICAGO, ROCK ISLAND & PACIFIC RAILROAD

SERVICE RECORDS OF TREATED TIES—1955 Sheet 2 of 2 sheets

Lowry Treatment

Kind of Ties	Lowry Treatment	Year Inserted	Original Number Inserted	Ties Removed Total	Ties Removed Percent	Ties Remaining in Track	Avg. Life of Ties to Date
Gum	Tiskilwa	1911	6	6	100	0	27.33
Gum	Ely	1911	344	344	100	0	24.62
Gum	Altoona	1911	299	299	100	0	30.42
Gum	Fairbury	1911	67	67	100	0	19.79
Pine	Tiskilwa	1911	69	69	100	0	21.97
Pine	E. Des Moines	1911	56	49	88	7	22.90
Pine	Clarksville	1911	1013	1000	99	13	30.99
Pine	West Bend	1911	809	669	83	140	34.81
Pine	Fairbury	1911	1496	1475	99	21	28.78
Pine	Goodland	1911	1603	1466	91	137	28.02
Pine	Topeka	1911	146	138	95	8	24.43
Elm	Altoona	1911	148	54	36	94	29.63
Red Oak	Tiskilwa	1912	194	175	90	19	21.65
Red Oak	Ely	1912	465	451	97	14	27.62
Red Oak	E. Des Moines	1912	5449	5019	92	430	27.04
Red Oak	Altoona	1912	750	750	100	0	28.74
Red Oak	Goodland	1912	83	82	99	1	32.18
Red Oak	Eldon	1912	2416	2284	95	132	31.79
Gum	Tiskilwa	1912	676	626	93	50	24.79
Gum	Ely	1912	1232	1211	98	21	25.02
Gum	E. Des Moines	1912	1253	1120	89	133	26.79
Pine	Tiskilwa	1912	40	40	100	0	19.82
Pine	Ely	1912	345	341	99	4	25.09
Pine	Clarksville	1912	1037	1017	98	20	30.00
Pine	West Bend	1912	711	639	90	72	34.64
Pine	Fairbury	1912	1370	1360	99	10	27.61
Pine	Goodland	1912	536	510	95	26	27.85
Pine	Topeka	1912	258	258	100	0	19.11
Pine	Dalhart	1912	255	255	100	0	26.02
Elm	Tiskilwa	1912	5	5	100	0	17.60
Elm	Ely	1912	144	139	97	5	22.94
Elm	E. Des Moines	1912	231	214	93	17	25.67
Beech	Tiskilwa	1912	73	71	99	2	21.90
Red Oak	Tiskilwa	1913	44	43	98	1	26.23
Red Oak	Ely	1913	1615	1600	99	15	28.02
Red Oak	Altoona	1913	491	491	100	0	29.04
Red Oak	Clarksville	1913	262	262	100	0	30.83
Red Oak	Eldon	1913	1262	1209	96	53	30.61
Red Oak	Topeka	1913	625	618	99	7	22.06
Gum	Tiskilwa	1913	805	761	95	44	22.80
Gum	Ely	1913	133	125	94	8	26.19
Gum	Altoona	1913	94	94	100	0	27.28
Gum	Topeka	1913	523	523	100	0	23.73
Gum	Dalhart	1913	114	75	66	39	28.65
Pine	Tiskilwa	1913	18	18	100	0	17.44
Pine	Ely	1913	80	79	99	1	24.73
Pine	Clarksville	1913	722	671	93	51	29.74
Pine	West Bend	1913	17	12	71	5	33.00
Pine	Fairbury	1913	1073	1032	96	41	27.63
Pine	Goodland	1913	2260	2172	96	88	27.45
Pine	Topeka	1913	304	304	100	0	18.09
Pine	Dalhart	1913	859	856	99	3	26.48
Elm	Tiskilwa	1913	6	6	100	0	20.16
Red Oak	Tiskilwa	1914	1181	1136	96	45	25.99
Red Oak	Ely	1914	2062	2005	97	57	27.60
Red Oak	Altoona	1914	2041	1954	96	87	24.95
Red Oak	Eldon	1914	553	537	97	16	30.81
Red Oak	Topeka	1914	701	699	99	2	22.16
Gum	Tiskilwa	1914	1338	1205	90	133	24.67
Gum	Clarksville	1914	408	282	69	126	31.21
Gum	Fairbury	1914	206	155	75	51	27.23
Gum	Goodland	1914	375	276	74	99	30.10
Gum	Eldon	1914	412	404	98	8	29.76
Gum	Topeka	1914	401	401	100	0	27.33
Gum	Dalhart	1914	71	29	41	42	27.86
Pine	Clarksville	1914	634	634	100	0	28.92
Pine	Fairbury	1914	696	648	93	48	27.66
Pine	Goodland	1914	2438	2184	90	254	28.52
Pine	Topeka	1914	563	563	100	0	18.82
Pine	Dalhart	1914	385	361	94	24	25.76

RECORD OF TEST SECTIONS

CROSS TIES - UNION PACIFIC RR. CO.

DATE 1955

Number	Reference	Location District	Location M.P.	Species	Installed Number	Installed Date	Conditioning	Treat. Process	Preservative	Retention PCF	Service Life to Date Min.	Max.	Ave.	Antic. Ave. Life	Removed Number	Removed Percent	Principal Cause of Removal	Remarks
1	2	Wells Brch.	31.93	Sawn West Coast Doug. Fir.	3148	1924	Air. Seas.	Bethel	AWPA #1 Creo.	8.0	18	31	30.09	45	417	13.25	Checking and Rot under side	From Pacific Coast
2	F	Orchard Boise ML	B-429.43	Sawn Ida. Red Fir	3081	1924	"	Lowry	"	8.0	17	31	27.48	31	1756	56.8	Splitting & Rot	From N. E. Idaho
3	C	"	B-430.12	Sawn Lodge Pole Pine	776	1924	"	"	"	8.0	20	31	29.63	38	269	34.7	Split & Checked	From S. W. Montana
4	H	"	B-430.72	Sawn Wstn. Yellow Pine	2579	1924	"	"	"	8.0	17	31	30.73	51	198	7.72	"	From No. Idaho
5	I	"	B-431.70	Sawn West Coast Doug. Fir	3028	1924	"	"	"	8.0	20	31	29.12	36	1034	34.2	"	42 damaged by derailment
6	J	"	B-432.46 B-433.41	Hn. Lodge Pole Pine	2555	1924	"	"	"	8.0	21	31	29.16	34	1169	45.7	Split & Center Rot	From No. Idaho
9	D	"	B-427.33	Sawn White Fir & Englemann Spruce	3131	1924	"	"	95/5% Creo-Petro.	9.0	25	31	30.13	42	800	25.5	Splits & Plate Cut at Joints	"
10	A	"	B-425.00	Sawn West Coast Doug-Fir	780	1924	"	"	50/50% Creo Petro.	8.0	12	31	30.37	50	129	16.5	Checks & Splitting	
11	1	Wyo. ML	928.00 WB	Sn. Lodge Pole Pine	1766	1942	"	Reup-ing	"	8.0	13	13	13	40	0	0	None	1° Curve 9' Ties
12	2	Oregon M.L.	30.00	Sn. Lodge Pole Pine	932	1946	"	Lowry	"	8.0	9	9	9	40	0	0	"	" "
13	1	Gay Spur Idaho	20.00	Sawn Inland Dee Fir	2916	1948	Artif. in Oil	"	50/50 Creo. Arom. Petro.	8.0	7	7	7	45	0	0	"	From Mt. Hood
14	1	Idaho M.L.	230.00	Sawn Noble Fir	691	1949	"	"	"	8.0	6	6	6	45	0	0	"	"
20	B	Orchard Boise M.L.	B-425.24	Sawn Idaho White Fir	782	1924	A.S.	"	30/70 Creo-Petro.	12.0	12	31	26.15	34	376	48.0	Plate Cut	From N.E. Idaho

RECORD OF TEST SECTIONS

CROSS TIES - UNION PACIFIC RR. CO.

DATE 1955

Number	Reference	Location District	Location M.P.	Species	Installed Number	Installed Date	Conditioning	Treat. Process	Preservative	Retention PCF	Service Life to Date Min.	Max.	Ave.	Antic. Ave. Life	Removed Number	Removed Percent	Principal Cause of Removal	Remarks
21	Wah-satch	Wyo. ML	928.00 WB	Sawn Lodge Pole Pine	1298	1942	A.S.	Lowry	30/70 Creo-Petro.	8.0	13	13	13	40	0	0	None	
22	1	Ore.ML	30.00	Sawn West Coast Doug. Fir	657	1946	"	"	25/75 Creo-Petro 5% Penta	8.0	9	9	9	50	0	0	one	
23	Arling	Idaho North	107.00	"	874	1947	"	"	"	8.0	8	8	8	50	0	0	None	From N.E. Idaho
34	6	Wells Br.	42.59	Sawn West Yellow Pine	3142	1924	"	Burnett 2-Pass	Zn.Cl. Petro	0.5 3#	17	29	26.21	36	3142	100.00	Plate Cut & Broken	From N.E. Idaho Complete
41	8	"	44.86	Sawn Idaho Red Fir	3219	1925	"	Burnett	Zn.Cl.	0.5	11	28	19.94	26	3219	100.0	Checked & Plate Cut	From N.E. Idaho Complete
48	10	"	55.44	Sawn Lodge Pole Pine	2298	1925	Air Seas.	Burnett 2-Pass	Zn.Cl. Petro	0.5 3#	14	28	23.92	30	2298	100.0	Checked & rot underside	From S.W. Montana, Complete
50	Hinkle Yd.	Ore. Divn.	186.0	Sawn Wstn Red Cedar	1439	1950	do	Lowry	50/50 Creo-Petr.	7.75	5	5	5	40	0	0	None	224 in Trk.1, 242 in Trk.2, 473 in Trk.18, 260 in Trk.19, 234 in Trk.20,:Chgs.74 & 83
51	1	Chian-Dale No. 3 WBML	512.32 512.55	Sawn Lodge Pole Pine	708	1952	Partial Air Seas.	do	do	8.04	3	3	3	45	0	0	None	6-4-54-Ties good, Very few splits or checks. No plate cut.
52	2	do	512.55 512.63	Sawn Wstn. Doug. Fir	235	do	Artif. in Oil	Boulton Lowry	50/50 Creo Petro.	8.07	3	3	3	50	0	0	None	
53	3	do	512.63 512.82	Sawn W.Y. Ponderosa Pine	500	do	do	Rueping	do	8.13	3	3	3	50	0	0	None	Some checks, No plate cut.
54	4	do	512.82 513.07	Sawn Wstn. Hemlock	766	do	do	do	do	8.20	3	3	3	45	0	0	None	No splits-checks or plate cut.

RECORD OF TEST SECTIONS

CROSS TIES - UNION PACIFIC RR. CO.

DATE 1955

Number	Reference	Location District	Location M.P.	Species	Installed Number	Installed Date	Conditioning	Treat. Process	Preservative	Retention PCF	Service Life to Date Min.	Max.	Ave.	Antic. Ave. Life	Removed Number	Removed Percent	Principal Cause of Removal	Remarks
55	5	Chian-Dale No. 3 WBML	513.07 513.23	Sawn Ida. White Fir	500	1952	Artif. in Oil	Rueping	50/50 Creo-Petro.	8.26	3	3	3	40	0	0	None	Some splits and checks
56	6	do	513.23 513.32	Sawn Wstn. Douglas Fir	265	do	do	Boulton Lowry	do	8.07	3	3	3	50	0	0	None	
57	7	do	513.32 513.50	Sawn Wstn. Yellow Pine Ponderosa	500	do	Air Seas.	Lowry	do	8.08	3	3	3	50	0	0	None	
58	8	do	513.50 513.60	Sawn Ida. White Fir	300	do	Artif. in Oil	Rueping	do	8.26	3	3	3	40	0	0	None	
59	9	do	513.60 513.69	Sawn Ida. Red Fir	800	do	do	Bethel	do	5.46	3	3	3	45	0	0	None	
60	10	do	513.69 513.86	Sawn Lodge Pole Pine	292	do	Air Seas.	Lowry	do	8.04	3	3	3	45	0	0	None	
61	11	do	513.86 514.03	Sawn Englemann Spruce	500	do	Artif. in Oil	Boulton Lowry	do	8.05	3	3	3	40	0	0	None	
62	12	do	514.03 514.19	do	500	do	Air Seas.	Lowry	do	8.05	3	3	3	40	0	0	None	
63	13	do	514.19 514.26	Sawn Wstn. Yellow Pine Ponderosa	200	do	Artif. in Oil	Rueping	do	8.13	3	3	3	45	0	0	None	
64	14	do	514.26 514.29	Sawn Wstn. Douglas Fir	100	do	Air Seas.	Empty Cell	Ark. Gas Oil	9.45	3	3	3	20	0	0	None	Dow Chem. Code 100
65	15	do	514.29 514.32	do	100	do	do	do	Gas Oil + 2.15%	10.29 Penta	3	3	3	25	0	0	None	Dow Chem. Code 102
66	16	do	514.32 514.35	do	100	do	do	do	Gas Oil + 2.97%	9.46 Penta	3	3	3	30	0	0	None	Dow Chem. Code 103

RECORD OF TEST SECTIONS

CROSS TIES - UNION PACIFIC RR. CO.

DATE - 1955

Sheet 4 of 4 sheets

Number	Reference	Location District	M.P.	Species	Installed Number	Installed Date	Conditioning	Treat. Process	Preservative	Retention PCF	Service Life to Date Min.	Max.	Ave.	Antic. Ave. Life	Removed Number	Removed Percent	Principal Cause of Removal	Remarks
67	17	Chian-Dale No. 3 Trk WBNL	514.35 514.39	Sawn Douglas Fir	100	1952	Air Seas.	Empty Cell	Gas-Oil #3.93% Penta	9.55	3	3	3	35	0	0	None	Dow Chem Code 104
68	18	do	514.39 514.42	do	100	1952	do	do	Gas-Oil #5.00% Penta	8.99	3	3	3	40	0	0	None	Dow Chem. Code 105
69	19	do	514.42 514.45	do	96	1952	Artif. in Oil	Vapor Drying	50/50 Creo-Petro	9.5	3	3	3	50	0	0	None	O.F.P. Tech.Rep. No. 6
70	20	do	534.16 534.38	Sawn Ida. White Fir	677	1952	Air Seas.	Rueping	do	8.08	3	3	3	40	0	0	None	Quite badly split on low side of curve.
71	21	do	534.38 534.61	Sawn Western Hemlock	689	1952	do	do	do	8.06	3	3	3	45	0	0	None	
72	22	do	534.61 534.80	Sawn Douglas Fir	667	1952	do	Lowry	do	8.07	3	3	3	50	0	0	None	
73	23	do	543.72 543.92	Sawn Ida. Red Fir	608	1953	do	Bethel	do	4.56	2	2	2	45	0	0	None	
74	24	do	554.15 554.38	Sawn Ark. Red Oak	686	1953	Artif. in Oil	Boulton Lowry	do	6.26	2	2	2	50	0	0	None	2° C.L. 7 x 9 x 9 - No. 5
75	75	Rawlins Daleys Ranch WBNL	684.15 684.37	Sawn Douglas Fir	672	1953	do	Lowry	do	8.09	2	2	2	50	0	0	None	Chg 695
76	76	do	684.37 684.50	Sawn Douglas Fir	400	1953	do	do	Gas-Oil #5.00% Penta	8.24	2	2	2	50	0	0	None	Chg 697
77	77	do	684.50 684.78	Sawn Ida. Red Fir	798	do	do	Bethel	50/50 Creo-Petro.	4.88	2	2	2	45	0	0	None	Chg 698
78	78	do	684.78 685.05	do	774	do	do	do	Gas-Oil #5.00% Penta	5.03	2	2	2	45	0	0	None	Chg 700
79	79	do	685.57 685.71	Sawn Douglas Fir	400	do	do	Lowry	do	8.24	2	2	2	50	0	0	None	Chg 697
80	80	WBNL	686.83 687.10	Sawn Western Hemlock	770	do	do	do	do	8.20	2	2	2	45	0	0	None	Chg 692
81	81	do	687.10 687.37	do	791	do	do	do	50/50 Creo-Petro	8.08	2	2	2	45	0	0	None	Chg 694
82																		
83																		
84																		

ILLINOIS CENTRAL RAILROAD

Sheet 1 of 2 sheets

STATUS OF CROSS TIES IN TEST SECTION - 1955

Location	Species	Number	Conditioning	Treating Process	Preservative Process	Retention Pcf.	Date Installed	Date last inspected	% Removed	Ind. Ave. Life Years	Principle cause of removal	Remarks
Canton, Miss.	S.Pine	1213	Air. S.	Pressure	Creo.	Unknown	1923	1955	99.9	15.4	Plate Cut	In 1954 the Canton Test sec. carried 5.5 million gross tons per mile traffic. Speed limit 79 mph.
"	"	1033	"	"	"	"	1924	1951	100.0	13.0	" "	Removal complete
"	"	550	"	"	"	"	1925	1951	100.0	15.2	" "	" "
"	"	1080	"	"	"	"	1926	1953	100.0	13.9	" "	" "
"	"	658	"	"	"	"	1927	1952	100.0	12.9	" "	" "
"	"	196	"	"	"	5-5½	1928	1947	100.0	12.2	" "	" "
"	"	661	"	"	"	"	1929	1955	99.6	12.6	Crushed	
"	"	880	"	"	"	"	1930	1955	97.2	14.0	"	
"	"	574	"	"	"	"	1931	1955	99.4	14.6	Plate Cut	
"	"	708	"	"	"	"	1932	1955	99.7	12.9	Crushed	
"	"	251	"	"	"	"	1933	1955	98.3	13.4	Plate Cut	
"	"	895	"	"	"	"	1934	1955	94.5	13.9	Plate Cut	
"	"	1068	"	"	70/30 Creo	7.0	1935	1955	85.7	17.0	" "	
"	"	574	"	"	60/40Creo-Pet.	8.0	1936	1955	78.4	17.0	" "	
"	"	202	"	"	60/40Coal Tar	7.0	1937	1955	78.8	16.0	Unknown	
"	"	845	4½ Mo. Air	Ruep.	60/40 Creo	6.8	1938	1955	93.6	10.5	Decay	
"	"	2814	4 Mo. Air	"	Coal Tar	7.5	1939	1955	43.9	18	Plate Cut	
"	"	2045	5 Mo. Air	"	50/50Creo-pet.	8.0	1940	1955	37.5	17	Plate Cut	
"	"	16	Air.	"	Creo.coal tar 60/40	7.0	1941	1955	19.0	19	Shake	
"	"	689	4½ Mo. Air	"	"	8.0	1942	1955	63.6	12	Decay	
"	"	1227	3 Mo. Air	Ruep.	"	8.0	1943	1955	19.5	16.1	Shake	
"	"	797	3 Mo. Air	"	70/30 "	7.0	1946	1955	3.8	-	Crushed	Less than 10% removed
"	"	796	3½ Mo. Air	"	"	7.1	1947	1955	1.2	-	Shake	" " " "
"	"	1303	6 Mo. Air	"	"	7.2	1948	1955	2.0	-	Unknown	" " " "
"	"	403	5½ Mo. Air	"	60/40 "	8.1	1950	"	1.0	-	"	" " " "
"	Oak	139	Air	Pressure	Creo	5 or less	1925	1942	100.0	13.4	Split	Removal complete
"	"	695	"	"	"	"	1926	1952	100.0	14.3	Split	" "
"	"	383	"	"	"	"	1928	1952	100.0	11.9	Split	" "
"	"	848	"	"	"	"	1929	1952	100.0	15.4	Split	" "
"	"	404	"	"	"	"	1930	1955	99.3	13.6	Split	
"	"	775	"	"	"	"	1931	1955	99.9	13.0	Split	
"	"	197	"	"	"	"	1932	1955	99.5	14.4	Split	

ILLINOIS CENTRAL RAILROAD

STATUS OF CROSS TIES IN TEST SECTION - 1955

Location	Species	Number	Conditioning	Treating Process	Preservative Process	Retention Pcf.	Date Installed	Date last inspected	% Removed	Ind. Ave. Life Years	Principle cause of removal	Remarks
Canton, Miss.	Oak	226	Air. S.	Pressure	Creo	5 or less	1933	1955	98.9	13.8	Split	
"	"	10	"	"	"	"	1934	1952	100.0	14.7	Split	Removal Complete
"	Gum	1	Air	"	"	"	1925	1952	100.0	27.0	Decay	
"	"	411	"	"	"	"	1931	1955	48.9	24	Split	
"	"	139	"	"	"	"	1933	"	49.6	23	"	
"	"	813	"	"	"	"	1934	"	29.1	26	"	
"	"	593	"	"	"	"	1936	"	20.9	25	"	
"	"	516	Osmose	Treatment			1937	1952	100.0	5.3	Decay	Removal complete
"	"	409	7½Mo.Air	Ruep	#1 Creo	7.0	1938	1955	3.7	-	Split	Less than 10% removed
"	"	398	Air	"	60/40 Creo-coal tar	7.0	1939	"	9.8	-	Split	
"	"	451	5 Mo.Air	"	#1 Creo.	8.0	1941	"	9.7	-	Decay	" " " "
"	"	809	4½Mo.Air	"	"	6.7	1942	"	17.9	18.0	Decay	
"	"	1036	3-6Mo.Air	"	"	6.9	1943	"	6.1	-	Decay	Less than 10% removed
"	"	298	4½Mo.Air	"	"	6.8	1944	"	4.0	-	Unknown	" " " "
"	"	298	6½Mo.Air	"	"	6.9	1946	"	6.1	-	Unknown	" " " "
"	"	797	2½Mo.Air	"	"	7.0	1947	"	2.5	-	Decay	" " " "
"	"	1461	4 Mo.Air	"	"	7.0	1948	"	3.3	-	Decay	" " " "
"	"	800	5 Mo.Air	"	"	7.3	1950	"	0.2	-	Unknown	" " " "
"	"	2050	8 Mo.Air	"	"	7.0	1951	"	0	-	-	None removed
"	"	296.5	Mo.Air	"	60/40 Creo-	9.9	1952	"	0	-	-	" "
"	"	263	Air	"	Coal Tar	9.9	1953	"	0	-	-	" "
"	"	514	8 Mo. Air	"	"	9.9	1955	"	0	-	-	" "
"	Cypress	10	Air	Pressure	Creo	Unknown	1923	1942	100.0	13.5	Spike Killed	Removal complete.
"	"	208	"	"	"	"	1924	1952	100.0	16.8	Plate Cut	" "
"	"	446	"	"	"	"	1926	1951	100.0	14.2	Plate Cut	" "
"	"	567	"	"	"	"	1927	1955	99.4	15.0	Plate Cut	
"	"	197	"	"	"	"	1928	"	99.4	15.9	Plate Cut	
"	Mixed Hardwoods	62	Air	Pressure	Creo.	Unknown	1925	1955	95.1	20.3	Split	

St. Louis-San Francisco Railway Company

Service Records of Treated Wood in Bridges on Western Division
Between Tulsa, Oklahoma and Enid, Oklahoma
Built in 1922

Piling - Southern Yellow Pine treated with 15 lb , 70 percent creosote, 30 percent coal tar solution.
Remaining timbers long leaf yellow pine treated with 12 lb creosote-distillate solution.

Bridge Number	Number of Panels	Maximum Height	Remarks
Z431.3	10	16 ft	Minor repairs to date but on 1955 program for renewal account of age and indicated increase in maintenance if kept in service. Minor repairs to balance of structure.
Z440.5	11	14 ft	Original ties replaced. Minor repairs to balance of structure.
Z442.5	7	17 ft	One decayed piling cut out and replaced with shore, other minor repairs. Propose to renew next year or two.
Z445.2	10	30 ft	Some deterioration of piling. Some stringers getting soft - starting to crush over caps. Propose to renew next year or two.
Z451.6	8	15 ft	Minor repairs to date and some trouble with piles driving under traffic, probably insufficient penetration.
Z453.5	10	24 ft	Original ties all replaced, minor repairs to balance of structure to date but some piling now showing signs of deterioration.
459.6	6	19 ft	Minor repairs.
468.4	3	8 ft	Original three ply stringer chord showed considerable deterioration and it was considered advisable to place another line of stringers in each chord making four ply.
482.5)	5	14 ft	These two bridges eliminated in 1954 by placing metal pipes and filling as part of program to replace older timber trestles with permanent type opening.
484.2)	7	19 ft	

Report on Assignment 3

Destruction by Marine Organisms: Method of Prevention

A. P. Richards (chairman, subcommittee), Walter Buehler, C. M. Burpee, G. L. Cain, R. R. Gunderson, H. M. Harlow, B. D. Howe, M. F. Jaeger, R. R. Poux, F. H. Taylor.

Your committee submits the following report as information relating to the activities of marine borers and methods of prevention.

At the present time there are no simple, fool-proof methods of insuring marine structures against destructive organisms. The recommended preservatives and practices are the result of many years of development and observation, and will usually be satisfactory if they are properly used. Unfortunately, careful attention must be paid to not only one factor but to a series of factors in order to obtain adequate structural materials. This outline deals only with wooden members.

1. *Timber*—In the selection of the proper species of wood for a given structure several different requirements must be met. It must always be borne in mind that the treatability of a species is important and must be considered as well as ultimate strength requirements. In this connection the depth of sapwood is of prime importance. All timber should be purchased under adequate specifications which will eliminate not only poor structural materials generally but also other characteristics which would reduce preservative penetration and retention, since borer activity will certainly begin at weak areas from a treatment viewpoint. In the case of most borers, once the organism has been able to gain entrance and grow to some size, the protective measures are less effective than they were against the immature stages. The timber should be inspected by qualified inspectors to guarantee adherence to the specifications.

2. *Preservative*—A number of preservatives are commercially available, each of which has characteristics which make it most suitable for some particular use. A preservative should also be chosen which is suitable to be used with the timber chosen. In the case of marine borer protection one of the prime factors to be considered appears to be permanence. There are a number of materials which could be used if only a short service life were desired, and often qualities such as cleanliness will make these desireable, in spite of the limited service life. As in the case of the timbers, it is most important that, once a proper selection is made, the material be purchased under complete and limiting specifications. Samples should be taken before treatment begins and for check purposes may be taken during the treating process. This class of materials is usually referred to in a general sense, while actually individual sources differ considerably from each other, making detailed specifications necessary.

3. *Method of Treatment*—Because of the different service purposes needed, several different methods of applying the preservative are in current use. These have been designed to give the treated wood characteristics desirable for different uses. For marine borer protection only, a treatment giving the maximum penetration and retention should be used that is consistent with not damaging the wood by the use of excessive pressures and temperatures. It is long term economy to provide a maximum of preservative. Penetration is as important as retention.

4. *Adequate Inspection*—The correct selection of materials is of no avail unless the purchaser is assured that he obtains delivery of the product he selects. One of the most important steps in the series is the use of informed and qualified inspectors before, during and after treatment. In this manner the preservative is constantly under observation,

the treating cycles are actually checked to prevent extreme conditions, and penetration and retention of the preservative are measured for conformity to the specifications. Only satisfactory pieces are accepted, thereby preventing the inclusion of undergrade material in the structure.

5. *Proper Handling After Treatment*—Even correctly treated material can be less effective and even worthless by careless handling. Slings rather than sharp pointed instruments should be used in order to protect piling. Framing, boring and cutting after treatment should be avoided wherever possible. In order not to introduce bends, piles should be carefully stacked before installation.

6. *Proper Structure Design*—In the past few years stress has been placed upon designs of marine structure which tend to eliminate points particularly susceptible to borer attack. A good example is the present trend to eliminate the use of horizontal and diagonal bracing below the water level. In the past the point of junction between bracing and piling, when under water, has often been the focal point of attack.

A proper combination of all the above mentioned factors will definitely result in improved service life. The underwater portions of marine structures are somewhat unique in that it is necessary to use greater care in the original construction because of the relative difficulties in making repairs.

Given below is further data relating to the activities of marine borers and methods of prevention.

TEST PILES

The following reports have been received from W. M. Jaekle, chief engineer, Southern Pacific Company:

Report of Inspection on December 28, 1954, of Specimens Furnished by Chemical Warfare Service and Placed in San Francisco Bay at Request of Dr. H. von Schrenk

Gate 25–1–A. Installed at Biological Station, Oakland Pier, July 21, 1925. Removed 1942, replaced 1946. The untreated pieces hung at this station, 1953–54, show heavy limnoria and very light bankia attack; loss in weight 23 percent.

No. 2 (Creosote and 1 percent diphenylamine chlorarsine). Heavy limnoria attack.

Chemical Warfare Service test pieces Forwarded from Edgewood Arsenal by Lt. Col. C. E. Brigham and Hung at Oakland Pier February 24, 1932; Removed 1942, Replaced 1946

Specimen	*Treatment and Retention*	*Condition*
A-11	Creosote 21.6 lb/cu/ft	Heavy limnoria attack on one side and in heartwood on ends; very light elsewhere.
D-11	Creosote plus 2½ dinitrophenol 23.7 lb/cu/ft	Moderate limnoria attack on sides; heavy attack in heartwood on ends.

Report of Inspection December 28, 1954, of Specimens Furnished Through Dr. H. von Schrenk and Col. Wm. G. Atwood and Installed in San Francisco Bay Area

Barrett Manufacturing Company material placed at Station B, Pier 7, San Francisco, January 1923. Moved to Biological Station, Oakland Pier, Southern Pacific Company, December 1925. Removed 1942, replaced 1946. Total exposure to date, 27 years. (P—Pine; F—Fir)

Gate	Specimen	Treatment	Condition Dec. 28, 1954
B-4	P-1	Coke oven original oil	Heavy limnoria attack.
	P-2	Coke oven solids removed	Heavy limnoria attack.
	P-3	Coke oven acids removed	Heavy limnoria attack.
	P-4	Coke oven bases removed	Heavy limnoria attack.
B-5	P-5	Coke oven oil minus residue at 360°C	Heavy limnoria attack.
	P-6	Coke oven oil minus fraction 230–270	Heavy limnoria attack.
	P-7	Coke oven oil minus fraction up to 230	Heavy limnoria attack.
	P-8	Coke oven oil minus fraction 270–360	Heavy limnoria attack.
B-6	P-9	Vertical retort original oil	Heavy limnoria attack.
	P-10	Vertical retort minus solids	Heavy limnoria attack.
	P-11	Vertical retort minus acids	Heavy limnoria attack.
	P-12	Vertical retort minus bases	Heavy limnoria attack.
B-7	P-13	Vertical retort minus residue above 360°C	Heavy limnoria attack.
	P-14	Vertical retort minus fraction 230–270°C	Heavy limnoria attack.
	P-15	Vertical retort minus fraction up to 230°C	Heavy limnoria attack.
	P-16	Vertical retort minus fraction 270–360°C	Heavy limnoria attack.
B-8	F-1	Same as P-1	Heavy limnoria attack.
	F-2	Same as P-2	Moderate limnoria attack.
	F-3	Same as P-3	Heavy limnoria attack.
	F-4	Same as P-4	Moderate limnoria attack.
B-9	F-5	Same as P-5	Heavy limnoria attack.
	F-6	Same as P-6	Heavy limnoria attack.
	F-7	Same as P-7	Heavy limnoria attack.
	F-8	Same as P-8	Heavy limnoria attack.
B-10	F-9	Same as P-9	Heavy limnoria attack.
	F-10	Same as P-10	Heavy limnoria attack.
	F-11	Same as P-11	Heavy limnoria attack.
	F-12	Same as P-12	Heavy limnoria attack.
B-11	F-13	Same as P-13	Heavy limnoria attack.
	F-14	Same as P-14	Heavy limnoria attack.
	F-15	Same as P-15	Heavy limnoria attack.
	F-16	Same as P-16	Heavy limnoria attack.

The untreated specimens at this station 1953–54, show heavy limnoria and very light bankia attack; loss in weight 23 percent.

Report of Inspection December 28, 1954 of Test Pieces Exposed to Marine Borers at Oakland Pier

The untreated test pieces exposed 1953–54 had heavy limnoria attack and light bankia attack; loss in weight, 23 percent.

A. Hercules Powder Co. products exposed 1948–54 show the following condition:
- Rosinamine D. Test piece No. 5 — Heavy limnoria attack.

B. Cuprolignum treated pieces exposed 1948–54 show the following conditions:
- Cu-3, pressure treated — Heavy localized limnoria attack.

C. Copper Naphtherate (pressure treated) piece, shows the following condition:
- CN, pressure treated — Heavy localized limnoria attack.

D. Four pieces placed April 5, 1950, show the following conditions:

Standard (of Calif.) Wood Preservative
- No. 1— 6.0 lb retention — Destroyed by limnoria 1954.
- No. 2—13.7 lb retention — Heavy limnoria attack.

Creosote
- No. 1—12.6 lb retention — Localized limnoria attack.
- No. 2— 6.2 lb retention — Heavy localized and light general limnoria attack.

E. Portland Gas & Coke Co. Five pieces treated with "Gasco" oils. Placed October 1951:
- HC, Gasco Creosote 14.6 lb/cu/ft — Very light limnoria attack.
- LC, Gasco Creosote 6.6 lb/cu/ft — Very light limnoria attack.
- HD, Gasco distillate 13.0 lb/cu/ft — Very light limnoria attack.
- MD, Gasco distillate 10.3 lb/cu/ft — Light limnoria attack.
- LD, Gasco distillate 3.9 lb/cu/ft — Light limnoria attack.

F. Eight pieces treated with various preservatives at West Oakland were placed January 20, 1954:
- PCPL—4% pentachlorophenol in toxisol WTL, 12.85 lb/cu/ft — Light limnoria attack.
- PCPH—10% pentachlorophenol in toxisol WTL, 12.62 lb/cu/ft — Moderate limnoria attack.
- CL —Creosote, 7.45 lb/cu/ft — No attack.
- CRM —Creosote, 18.97 lb/cu/ft — No attack.
- CM —Creosote, 10.58 lb/cu/ft — Light localized limnoria attack.
- CRL —Creosote, 13.24 lb/cu/ft — Very light localized limnoria attack.
- CH —Creosote, 11/21 lb/cu/ft — No attack.
- CDL —Petroleum diluent oil, Shell — Heavy localized attack.

TEST BOARD STUDIES

Marine borer test panel studies are being continued primarily for the purpose of (1) identifying the species present; (2) determining the extent of activity over extended periods of time; (3) fixing the breeding dates at each locality; and (4) correlating, if possible, the relationship of the above data with physical and chemical conditions of the water. This overall program is being sponsored by:

1. The New England Marine Piling Investigation.
   Committee chairman, S. G. Phillips, chief engineer, Boston & Marine Railroad.
2. The New York Harbor Marine Borer Research Committee.
   Committee chairman, Roger Gilman, director of port development, New York Port Authority.
3. Navy Department, Bureau of Yards and Docks.

These investigations involve the placing of untreated test panel assemblies at well over 300 locations distributed on a world-wide basis. The design of the assemblies is such that each month a pair of panels is removed and forwarded to the laboratory for examination. One of these panels has been submerged for 1 month, the other for a longer period, usually 8 months. From a series of such panels it is possible to obtain the information described above.

The following is an abstract of the results of the studies during the past year in the United States.

Study of the test board data indicates that heavy attacks by marine borers which would cause rapid destruction to unprotected submerged timber is taking place at the following locations:

TEREDINIDAE

Massachusetts
- Salem
- Buzzards Bay
- New Bedford
- Woods Hole
- Edgartown

New York
- Fishers Island
- Atlantic Beach
- Fire Island

Virginia
- Yorktown
- Norfolk
- Portsmouth

Florida
- Mayport
- Daytona Beach
- Fort Pierce
- Key West
- St. Petersburg
- Panama City
- Pensacola

Rhode Island
- Goat Island
- Coddington Cove
- Block Island

New Jersey
- Barnegat City

North Carolina
- Morehead City
- Wrightsville Beach
- Southport

Texas
- Sabine
- Galveston
- Port Isabel

Connecticut
- South Groton
- Mystic
- New London
- Niantic

Delaware
- Lewes

South Carolina
- Charleston

Washington
- Bellingham
- Friday Harbor
- Neah Bay
- Port Angeles
- Port Townsend
- Indian Island
- Everett
- Bremerton
- Seattle
- Tacoma
- Olympia

California
Samoa
Yerba Buena Island
San Francisco
Santa Barbara
Port Hueneme
Santa Monica
San Pedro
San Diego

LIMNORIA

Maine
Rockland
Portland

Massachusetts
Salem
Charlestown
East Boston
South Boston
Hull
Quincy
New Bedford
Woods Hole

Rhode Island
Newport
Block Island

Connecticut
Mystic
New London

New York
Fishers Island

North Carolina
Morehead City
Wrightsville Beach
Southport

Florida
Mayport
Fort Pierce
Key West
St. Petersburg
Pensacola

Texas
Port Isabel

Washington
Port Angeles
Friday Harbor
Neah Bay

California
San Pedro
Monterey

Marine borer activity, while not shown to be of maximum intensity during the test board studies, could cause destruction over a period of time at the following locations:

TEREDINIDAE

Newfoundland
Corner Brook

Maine
Searsport
Rockland
Thomaston
Portland
Scarboro
York

New Hampshire
Portsmouth

Massachusetts
Gloucester
Beverly
Lynn
West Lynn
South Boston
Hull
Weymouth
Duxbury
Chatham

Rhode Island
Tiverton
Quonset Point

Connecticut
Allyn's Point
Saybrook
Guilford
New Haven
Bridgeport
Norwalk

New York
Pelham Bay
Manhattan, North River
Jamaica Bay
Rosebank, Staten Island
Sayville, Long Island

New Jersey
Bayonne

Maryland
Annapolis

Virginia
Lee Hall
James River Fleet

North Carolina
Wilmington

Alabama
Mobile

California
Mare Island
Benicia
Port Chicago
Monterey

LIMNORIA

Newfoundland
Corner Brook
Argentia

Nova Scotia
Liverpool

Maine
Searsport
Southwest Harbor
Wiscasset
York

New Hampshire
Portsmouth

Massachusetts
Gloucester
Beverly
Lynn
Hingham
Weymouth
Edgartown

Rhode Island
Tiverton
Quonset Point

Connecticut
South Groton
Niantic

New York
Pelham Bay
Brooklyn, foot of 26th Ave.
Jamaica Bay
St. George, Staten Island
Rosebank, Staten Island
Fire Island

New Jersey
Bayonne
Barnegat City

Florida
Daytona Beach
Panama City

Texas
Galveston
Corpus Christi

Washington
Bellingham
Port Townsend
Indian Island
Everett
Bremerton
Seattle
Tacoma
Olympia

California
San Francisco
Yerba Buena Island
Santa Barbara
Port Hueneme
Santa Monica
San Diego

Results obtained from studies at the following locations do not indicate the probability of serious damage by marine borers, although these animals are present to some extent. These areas are actually the most critical, since conditions are apparently suitable to support a few organisms. It would definitely seem that a relatively minor shift in these conditions in a suitable direction would result in much increased activity.

TEREDINIDAE

Newfoundland
Argentia

Nova Scotia
Liverpool

Maine
Machiasport
Southwest Harbor
Bucksport
Wiscasset

Massachusetts
Charlestown
East Boston
Neponset
Quincy
Hingham

Rhode Island
Providence

New York
Hunt's Point
East River
Astoria
Brooklyn
Naval Shipyard
Fulton Terminal
56th St. Yard
Army Base
Brooklyn, Ft. of 26th Ave.
Jamaica Bay
Newark Bay
St. George, Staten Is.

New Jersey
Hoboken
Perth Amboy
Leonardo Piers, Sandy Hook Bay

Maryland
Baltimore

Alabama
Bay Minette

Texas
Beaumont

LIMNORIA

Maine
Machiasport
Thomaston
Scarboro

Massachusetts
West Lynn
Neponset
Duxbury
Chatham
Buzzards Bay

Connecticut
Allyn's Point
Saybrook
Guilford
Bridgeport
Norwalk

New York
Hunt's Point
East River
North River
Astoria
Brooklyn Naval Shipyard
Atlantic Terminal
Fulton Terminal
56th St. Yard
Brooklyn Army Base
Newark Bay, Staten Is.
Atlantic Beach
Sayville

New Jersey
Hoboker
Leonardo Piers, Sandy Hook Bay

Delaware
Lewes

Virginia
Norfolk
Portsmouth

South Carolina
Charleston

Alabama
Bay Minette

Texas
Beaumont

California
Samoa
Mare Island
Benicia
Port Chicago

(All states listed geographically from left to right)

Report on Assignment 5

Destruction by Termites; Methods of Prevention
Collaborating with Committees 6 and 7

F. J. Fudge (chairman, subcommittee), W. Buehler, W. H. Fulweiler, H. M. Harlow, M. F. Jaeger, J. W. McGlothlin, A. P. Richards, H. C. Todd, Jr.

Your committee has requested from the Association of American Railroads approval of an appropriation in 1956 to establish a test plot on the property of the University of Florida for wood preserved against termite attack.

Details of this test to incorporate nine preservatives, three retentions, and three species of wood, are being planned at this time.

If this project is approved and established, progress reports on it will be made by the committee as pertinent information is developed.

Report on Assignment 6

New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products

A. P. Richards (chairman, subcommittee), J. A. Barnes, P. D. Brentlinger, H. B. Carpenter, W. H. Fulweiler, M. S. Hudson, H. E. Hurst, R. R. Poux, R. B. Radkey, B. J. Richards, H. M. Schudlich.

The committee submits herein a specification for a new water-borne preservative and recommends that it be adopted for publication in the Manual. This preservative, chromated zinc arsenate, commercially known as Boliden Salt, has been approved as standard by the American Wood Preservers' Association.

The U. S. patent on this preservative expired on December 13, 1955, so this material is now eligible for approval by the Association.

This salt has been used extensively in Sweden and other Scandinavian countries, and since World War II, has been introduced to a number of European countries as well as South America and the United States. It has shown up well in test stations in various parts of the world, as indicated on pages 34 and 35 of the American Wood Preservers' Association Proceedings for 1949.

Chromated zinc arsenate presents no particular health hazard, although workers handling concentrated solutions should be protected by the suitable safety equipment ordinarily employed with arsenic and chromium compounds. It is practically noncorrosive, imparts some fire retardance to the treated wood, and apparently has no marked effect on the strength of wood. To prevent sludging in treating solutions, the treating temperature should not exceed 120 deg F.

The following specification is recommended for adoption and publication in the AREA Manual, along with the appended comment.

CHROMATED ZINC ARSENATE

Chromated zinc arsenate in the solid state shall be composed of the following ingredients in the proportions given:

Arsenic Acid (H_3AsO_4)	21
Sodium arsenate (Na_2HAsO_4)	20
Sodium dichromate ($Na_2Cr_2O_7.2H_2O$)	16
Zinc sulphate* ($ZnSO_4.7H_2O$)	43

*An equivalent amount of zinc sulphate ($ZnSO_4 . 5H_2O$) may be used in place of $ZnSO_4 . 7H_2O$.

The proportions of the ingredients in the solid preservative or in treating solution shall conform to the following minimums:

Arsenic acid (H_3AsO_4)	10
Sodium arsenate (Na_2HAsO_4)	18
Sodium dichromate ($Na_2Cr_2O_7.2H_2O$)	14
Zinc sulphate ($ZnSO_4.7H_2O$)	41

The solid preservative shall be considered to meet the requirements with respect to arsenic compounds if the total arsenic content calculated as As_2O_5 is not less than 27 percent and the pH of a solution containing 25 grams per liter of the solid preservative measured at 25 deg C lies between 2.90 and 3.50.

The preservative shall contain at least 95 percent of the active ingredients listed above.

Tests to establish conformity with the foregoing requirements shall be made in accordance with the current standard methods of the American Wood-Preservers' Association.

COMMENT

Chromated zinc arsenate is recommended for preservative treatment of all classes of wood except marine piling. However, salt treatments as a general rule have not been found entirely satisfactory for cross ties because they do not help to protect the wood mechanically as do oily type preservatives.

For general use where leaching is not an important factor, the following retentions of chromated zinc arsenate are recommended:

For use in contact with the ground, not less than 1.0 lb/cu/ft; for use above ground, not less than 0.5 lb/cu/ft.

Report on Assignment 8

Effect on AREA Standards and Specifications of Any Changes in Manufacturing Processes and Specifications for Creosote, Petroleum and Other Products

W. W. Barger (chairman, subcommittee), Walter Buehler, C. M. Burpee, W. H. Fulweiler, M. S. Hudson, A. P. Richards, B. J. Richards.

Under a special assignment your committee has prepared the accompanying table showing Volume Correction Factors for Preservative Salt Solutions, and recommends that it be adopted for publication in the Manual. This table of factors is considered

VOLUME CORRECTION FACTORS FOR PRESERVATIVE SALT SOLUTIONS

FACTORS FOR CALCULATING VOLUMES* OF PRESERVATIVE SALT SOLUTIONS AT 100 DEG F WHEN OBSERVED AT TEMPERATURES RANGING FROM 60 TO 170 DEG F

Observed Temp. Deg F	Factors for solutions having concentrations of:					
	1%	2%	3%	4%	6%	8%
60	1.0057	1.0061	1.0065	1.0070	1.0077	1.0084
62	1.0053	1.0059	1.0063	1.0067	1.0074	1.0080
64	1.0050	1.0057	1.0060	1.0064	1.0071	1.0076
66	1.0048	1.0055	1.0057	1.0060	1.0068	1.0072
68	1.0046	1.0052	1.0054	1.0057	1.0064	1.0068
70	1.0044	1.0049	1.0050	1.0053	1.0060	1.0063
72	1.0041	1.0046	1.0047	1.0050	1.0056	1.0059
74	1.0038	1.0044	1.0044	1.0046	1.0052	1.0055
76	1.0035	1.0041	1.0041	1.0043	1.0048	1.0052
78	1.0033	1.0038	1.0038	1.0040	1.0044	1.0048
80	1.0030	1.0035	1.0035	1.0037	1.0040	1.0044
82	1.0027	1.0033	1.0032	1.0033	1.0037	1.0040
84	1.0024	1.0030	1.0028	1.0030	1.0033	1.0036
86	1.0022	1.0026	1.0025	1.0026	1.0029	1.0031
88	1.0019	1.0023	1.0022	1.0022	1.0025	1.0027
90	1.0016	1.0019	1.0019	1.0019	1.0021	1.0023
92	1.0013	1.0015	1.0015	1.0015	1.0017	1.0018
94	1.0010	1.0012	1.0012	1.0012	1.0013	1.0013
96	1.0006	1.0008	1.0008	1.0008	1.0009	1.0009
98	1.0003	1.0004	1.0004	1.0004	1.0005	1.0005
100	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
102	.9996	.9997	.9996	.9995	.9996	.9995
104	.9992	.9993	.9992	.9991	.9992	.9991
106	.9989	.9989	.9988	.9987	.9987	.9986
108	.9985	.9985	.9984	.9983	.9982	.9981
110	.9981	.9980	.9980	.9979	.9977	.9976
112	.9978	.9977	.9976	.9975	.9972	.9971
114	.9974	.9973	.9972	.9970	.9967	.9966
116	.9970	.9969	.9968	.9965	.9963	.9961
118	.9966	.9965	.9964	.9961	.9959	.9956
120	.9962	.9961	.9959	.9956	.9954	.9950
122	.9958	.9957	.9954	.9951	.9949	.9944
124	.9954	.9954	.9950	.9947	.9945	.9939
126	.9950	.9950	.9946	.9943	.9940	.9933
128	.9946	.9945	.9941	.9938	.9934	.9928
130	.9942	.9940	.9936	.9933	.9929	.9922
132	.9937	.9935	.9931	.9928	.9924	.9919
134	.9932	.9930	.9926	.9923	.9919	.9910
136	.9927	.9924	.9921	.9917	.9914	.9904
138	.9922	.9919	.9916	.9911	.9908	.9898
140	.9917	.9914	.9910	.9906	.9902	.9893
142	.9911	.9908	.9904	.9900	.9897	.9887
144	.9906	.9903	.9899	.9895	.9891	.9881
146	.9901	.9898	.9894	.9889	.9885	.9875
148	.9896	.9892	.9888	.9883	.9879	.9869
150	.9890	.9886	.9882	.9877	.9873	.9864
152	.9885	.9881	.9877	.9871	.9867	.9858
154	.9880	.9876	.9872	.9865	.9860	.9851
156	.9875	.9871	.9866	.9859	.9854	.9845
158	.9869	.9865	.9859	.9853	.9848	.9838
160	.9863	.9859	.9853	.9846	.9841	.9832
162	.9857	.9853	.9847	.9839	.9835	.9825
164	.9851	.9846	.9840	.9833	.9828	.9818
166	.9845	.9839	.9833	.9826	.9821	.9811
168	.9839	.9833	.9827	.9819	.9815	.9804
170	.9833	.9826	.9821	.9812	.9808	.9797

* To obtain volume of solution at 100 deg F, multiply observed volume by factor corresponding to observed temperature and concentration of the solution.

FACTORS FOR CALCULATING VOLUMES* OF PRESERVATIVE SALT SOLUTIONS AT 100 DEG F WHEN OBSERVED AT TEMPERATURES RANGING FROM 60 TO 170 DEG F (cont'd)

Observed Temp. Deg F	Factors for solutions having concentrations of:					
	10%	12%	14%	16%	18%	20%
60	1.0093	1.0098	1.0106	1.0112	1.0119	1.0123
62	1.0089	1.0094	1.0101	1.0106	1.0113	1.0117
64	1.0085	1.0089	1.0096	1.0100	1.0107	1.0111
66	1.0080	1.0085	1.0091	1.0095	1.0101	1.0105
68	1.0076	1.0080	1.0086	1.0090	1.0096	1.0099
70	1.0071	1.0075	1.0081	1.0084	1.0090	1.0093
72	1.0067	1.0070	1.0076	1.0078	1.0084	1.0087
74	1.0062	1.0065	1.0071	1.0073	1.0079	1.0082
76	1.0057	1.0060	1.0065	1.0068	1.0073	1.0076
78	1.0053	1.0056	1.0060	1.0062	1.0067	1.0070
80	1.0048	1.0051	1.0055	1.0056	1.0061	1.0064
82	1.0043	1.0046	1.0050	1.0051	1.0054	1.0058
84	1.0039	1.0041	1.0045	1.0046	1.0048	1.0051
86	1.0034	1.0036	1.0039	1.0041	1.0042	1.0045
88	1.0029	1.0031	1.0034	1.0035	1.0036	1.0039
90	1.0024	1.0026	1.0029	1.0030	1.0030	1.0032
92	1.0019	1.0021	1.0023	1.0024	1.0024	1.0026
94	1.0015	1.0016	1.0017	1.0018	1.0018	1.0020
96	1.0010	1.0010	1.0012	1.0012	1.0012	1.0013
98	1.0005	1.0005	1.0006	1.0006	1.0006	1.0007
100	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
102	.9995	.9995	.9994	.9994	.9994	.9993
104	.9990	.9989	.9988	.9988	.9987	.9986
106	.9985	.9984	.9983	.9982	.9981	.9980
108	.9980	.9978	.9978	.9976	.9975	.9974
110	.9974	.9973	.9972	.9970	.9969	.9967
112	.9969	.9967	.9966	.9964	.9962	.9961
114	.9964	.9961	.9961	.9958	.9956	.9955
116	.9958	.9955	.9955	.9952	.9949	.9948
118	.9953	.9949	.9949	.9945	.9943	.9941
120	.9947	.9943	.9944	.9939	.9936	.9934
122	.9941	.9937	.9938	.9933	.9930	.9928
124	.9935	.9931	.9932	.9926	.9924	.9921
126	.9930	.9925	.9926	.9919	.9917	.9914
128	.9924	.9919	.9919	.9913	.9910	.9907
130	.9919	.9913	.9913	.9907	.9904	.9900
132	.9913	.9907	.9907	.9900	.9897	.9893
134	.9907	.9901	.9900	.9893	.9890	.9887
136	.9901	.9894	.9893	.9886	.9883	.9880
138	.9895	.9888	.9887	.9879	.9876	.9873
140	.9889	.9882	.9881	.9873	.9869	.9866
142	.9882	.9876	.9874	.9866	.9862	.9859
144	.9876	.9870	.9867	.9859	.9855	.9852
146	.9870	.9864	.9861	.9852	.9848	.9845
148	.9863	.9857	.9854	.9846	.9841	.9837
150	.9857	.9851	.9848	.9839	.9834	.9830
152	.9850	.9844	.9841	.9832	.9827	.9823
154	.9844	.9837	.9834	.9825	.9820	.9815
156	.9837	.9831	.9827	.9818	.9813	.9807
158	.9831	.9824	.9820	.9811	.9806	.9800
160	.9824	.9817	.9813	.9804	.9798	.9793
162	.9817	.9810	.9806	.9797	.9791	.9785
164	.9810	.9803	.9799	.9789	.9783	.9778
166	.9803	.9796	.9791	.9782	.9775	.9770
168	.9796	.9789	.9783	.9774	.9768	.9762
170	.9789	.9783	.9776	.9767	.9760	.9754

* To obtain volume of solution at 100 deg F, multiply observed volume by factor corresponding to observed temperature and concentration of the solution.

necessary because of addition of a number of water soluble salt preservatives to the AREA list of standard preservatives during the past few years. The table gives factors for calculating volumes of preservative salt solutions at 100 deg F when observed at temperatures ranging from 60 to 170 deg F. The factors cover salt concentrations from 1 to 20 percent.

Report on Assignment 9

Treatment of Wood to Make It Fire Resistant

Collaborating with Committees 6 and 7

W. H. Fulweiler (chairman, subcommittee), W. W. Barger, R. S. Belcher, P. D. Brentlinger, L. C. Collister, T. H. Friedlin, F. J. Fudge, H. M. Harlow, M. S. Hudson, J. W. McGlothlin, R. R. Poux, H. C. Todd, Jr., C. H. Wakefield.

Your committee submits for adoption and publication in the Manual the following specification covering fire-retardant formulations and method of pressure treatment to make wood fire resistant, together with the appended comment. This specification is based on current American Wood-Preservers' Association standards.

SPECIFICATION FOR PRESSURE TREATMENT OF WOOD TO MAKE IT FIRE RESISTANT

FIRE-RESISTANT FORMULATIONS (WATER BORNE)

Formulation 1 (Chromated Zinc Chloride)

Shall conform to AREA requirements for chromated zinc chloride, Part 2, this Chapter.

Formulation 2

Shall be composed of the following ingredients in the proportions given:

Chromated zinc chloride	80	72 min
Ammonium sulfate	10	8 "
Boric acid	10	8 "

Formulation 3

Shall be composed of the following ingredients in the proportions given:

Diammonium phosphate	10	8 min
Ammonium sulfate	60	54 "
Sodium tetraborate	10	8 "
Boric acid	20	16 "

Formulation 4

Shall be composed of the following ingredients in the proportions given:

Zinc chloride	35	33 min	37 max
Ammonium sulfate	35	33 "	37 "
Boric acid	25	23 "	27 "
Sodium bichromate	5	3 "	7 "

Tests to establish conformity with the foregoing requirements of Formulations 2, 3, and 4 shall be made in accordance with the current standard methods of the American-Wood Preservers' Association (see AWPA Manual, Standards A2 and P10).

Lumber and timbers shall be treated for fire resistance or fire retardance in accordance with AREA Specific Requirements for Preservative Treatment by Pressure Processes, Part 4, this Chapter, except as modified or supplemented by the accompanying table.

	Southern Pine	Pacific Coast Douglas Fir	Red Oak
CONDITIONING	Air seasoning, kiln drying or steaming.	Air seasoning, kiln drying or steaming.	Air seasoning or kiln drying
Steaming			
Temp.--deg F--max	259	240	Not permitted
Duration--hr--min	-	3	
max	15	6	
Vacuum			
Inches at sea level min	22	22	
Duration-hr--min	1	1/2	
max	3	2	
Incising	Recommended when material is over 3" in thickness.	Required when material is over 3" in thickness.	Not recommended.
TREATMENT			
Method	Full-Cell	Full-Cell	Full-Cell
Pressure-psi-max	200	150	200
Temp-deg F--max			
Formulation 1--Chromated Zinc Chloride	140	140	140
Formulation 2	140	140	160
Formulation 3	160	160	160
Formulation 4	140	140	140
RESULTS OF TREATMENT			
Retention-lb per cu ft--min (all above formulations)			
Not over 2" thick	3.0	2.5	3.0
Over 2" up to 4" thick	2.5	2.0	2.5
Over 4" up to 8" thick	2.0	1.5	2.0
Over 8" thick	1.5	0.75	1.5
Penetration--in--min both heart and sap faces	1/2	1/2	1/2
Determination of penetration	A borer core shall be taken from 20 pcs in each charge. If 80% of the borings meet requirements the charge shall be accepted.	A borer core shall be taken from 20 pcs in each charge. If 80% of the borings meet requirements the charge shall be accepted.	A borer core shall be taken from 20 pcs in each charge. If 90% of the borings meet requirements and the average penetration of the 20 borings meets the requirements the charge shall be accepted.

Comment

Certain lumber substantially treated in accordance with the above specification has been tested for flame spread and rated by Underwriters' Laboratories, Inc., based on their "Fire Hazard Classification Test of Building Materials". The ratings obtained are shown below and apply when the material is treated with a certain minimum concentration of solution and is to be used on the interior of buildings.

Underwriters' Laboratories, Inc., Flame Spread Rating

(Based on rating of 0 for asbestos cement board and 100 for untreated red oak)

Formulation	*One-inch Southern Pine Lumber (100% Penetration)*	*One-inch Douglas Fir Lumber (100% Penetration)*
1—Chromated Zinc Chloride	35	35
2	25–35	35–40
3	40	..

Formulation	*Douglas Fir Lumber of Any Thickness (⅜ in Min Penetration)*
3	40

In addition to the above Underwriters' flame spread ratings the following ratings have been assigned to certain lumber treated in accordance with the above specifications but with heavier retentions of fire retardant. The ratings apply when the material is treated with a certain minimum concentration of solution and is to be used on the interior of buildings.

Underwriters' Laboratories, Inc., Flame Spread Rating

(Based on rating of 0 for asbestos cement board and 100 for untreated red oak)

Formulation	*One-inch Southern Pine Lumber (100% Penetration)*	*One-inch Douglas Fir Lumber (100% Penetration)*
3 (Retention 6 lb per cu ft)	30	..
4 (Retention 5 lb per cu ft)	..	20–30
4 (Retention 6 lb per cu ft)	25	..

Formulation	*Douglas Fir Lumber of Any Thickness (⅜ in Min Penetration)*
3 (Retention 5 lb per cu ft)	30

Note: The committee feels that further research is desirable in order to establish more fully the degree of fire resistance which will be provided by treatment in accordance with this specification.

Report on Assignment 12

Treatment of Laminated Timbers

Collaborating with Committee 7

L. C. Collister (chairman, subcommittee), W. W. Barger, P. D. Brentlinger, Walter Buehler, C. S. Burt, G. B. Campbell, R. F. Dreitzler, H. R. Duncan, R. R. Gunderson, R. R. Poux, R. B. Radkey, B. J. Richards.

This is a progress report, submitted as information.

Committee 7 last year drafted a specification for glued laminated timber which was published in the Proceedings, Vol. 55, 1954, page 568, adopted by the Association at the Annual meeting in March 1955, and made a part of the 1955 Manual Supplement.

Committee 7 is doing considerable fundamental research regarding the investigation of fire retardant coatings on timber trestles, and your committee will watch for any developments pertaining to the fire-retardant treatment of laminated timbers.

No new installations of treated laminated timbers has been called to the attention of your committee.

Report of Committee 27—Maintenance of Way Work Equipment

N. W. Hutchison,
Chairman,

A. W. Munt,
Vice Chairman,
S. H. Knight, *Secretary,*
R. M. Baldock
Edgar Bennett
R. E. Berggren
C. T. Blume
I. M. Boone
W. S. Brown
R. E. Buss
L. B. Cann, Jr.
E. L. Cloutier
G. R. Collier
L. E. Conner
F. L. Etchison
C. L. Fero
S. E. Haines
H. H. Hall
W. T. Hammond
F. L. Horn
Haynie Hornbuckle
Herbert Huffman
R. K. Johnson
M. E. Kerns
W. F. Kohl
W. E. Kropp
Jack Largent
C. F. Lewis
J. A. Mann
Francis Martin
Paul Martin
Harry Mayer
F. H. McKenney
E. L. Mire
C. W. Mitchell
C. E. Morgan
E. H. Ness
H. C. Nordstrom
V. W. Oswalt, Sr.
P. G. Petri
T. M. Pittman
T. I. Reagan
J. E. Reynolds
J. W. Risk
F. E. Short
R. J. Smith
M. M. Stansbury
R. S. Stephens
G. M. Strachan
W. B. Super
M. C. Taylor
T. H. Taylor
H. A. Thyng
S. E. Tracy
A. H. Whisler
F. E. Yockey

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Motor cars, trailer and push cars, collaborating with Signal Section, AAR Committee 10.

   No report.

3. New developments in work equipment.

   Progress report, submitted as information ..... page 474

4. Improvements to be made to existing work equipment.

   Progress report, submitted as information ..... page 488

5. Pneumatic tires and tubes.

   Final report, submitted as information ..... page 490

6. Storage batteries.

   Final report, submitted as information ..... page 496

7. Devices for warning forces of approaching trains.

   Final report, submitted as information ..... page 504

8. Care and operation of work equipment in freezing weather.
Final report, submitted as information ..... page 505

9. Track lining equipment.
Final report, submitted as information ..... page 514

10. Additional types of work equipment desired.
Final report, submitted as information ..... page 518

11. Off-track trailers for housing maintenance forces.
Final report, submitted as information ..... page 519

The Committee on Maintenance of Way Work Equipment,
N. W. Hutchison, *Chairman.*

AREA Bulletin 526, December 1955.

Report on Assignment 3

New Developments in Work Equipment

H. H. Hall (chairman, subcommittee), E. L. Cloutier, Francis Martin, Harry Mayer, F. H. McKenney, R. J. Smith, R. S. Stephens, T. H. Taylor.

This is a progress report, presented as information.

Previous reports on this subject are to be found in the Proceedings, Vols. 45, 50, 52, 53, 54, 55, and 56. The current report covers machines marketed since the last report, with the exception of those that are designated as track lining equipment which are reported separately under Assignment 9, and off-track trailers for housing maintenance forces which are reported separately under Assignment 11. This report includes, at its end, the major improvements or additions that have been made to existing machines.

Airless Spray Painting System

A new process of spraying paint without the use of air, which utilizes the internal forces of expansion of preheated paint to furnish the atomizing action causing the spray, has been introduced. There are two of these actions, the first being the mechanical force of the liquid coming out of a restricted orifice, and the second, the vaporization of the heated solvents. It is reported that paint over-spray and rebound are drastically reduced.

A gear pump rated at 35 gpm (150 rpm) syphons material from a 5-gal can or other suitable container. A fluid pressure ranging from 300 to 500 psi is built up in the circuit on the outlet side of the pump. The paint material is then passed through a 4000-watt explosion-proof heater which elevates and controls the temperature of the material to any predetermined value. This lowers the viscosity of the material to a watery consistency which makes it easier to atomize and builds up a vapor pressure whereby the tail-end fractions of the solvent are brought to the boiling point. Upon release of the material to the atmosphere, the flashing off of the solvents aids in atomization. In this process paints are heated to a temperature of from 140 to 180 deg F.

The heated material is constantly recirculated through the spray gun regardless of whether or not paint is benig sprayed.

Air-Powered Saw

An air-powered saw, designed for use in continuous, heavy-duty construction service, has been announced. This new saw is powered by a 3½-hp, 5-cylinder, radial-piston air motor which requires 85 cu ft of air per minute. It is reported that this air motor is sufficiently powerful to develop positive and uniform torque at all speeds, which is said to eliminate the need for racing the motor to secure power.

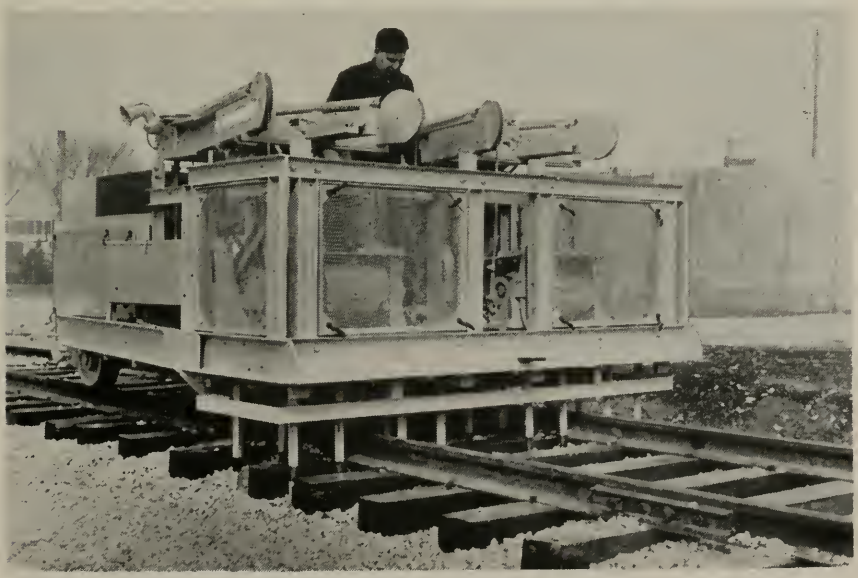
The unit weighs 46 lb and is equipped with a 2-strand, alloy-steel chain which removes a kerf of only 5/16 in. Ball bearings have been used throughout the machine, and the cutter bar carries a spring-loaded, ball-bearing-mounted roller which is said to reduce friction and wear and to automatically apply power-chain tension. The machine features a high-carbon-steel cutter bar with an easily replaceable wearing strip. The saw can be used for under-water cutting.

Automatic Gang Tamper

A production-type tamping machine which uses a different principle of vibration and a completely automatic tamping cycle is now available. The machine is equipped with split tamping heads which, the manufacturer claims, makes it adaptable for either out-of-face or spot tamping. It is one-man operated.

Power is supplied from a 32-hp, 4-cylinder, air-cooled gasoline engine. This is transmitted to all parts of the machine through a fluid coupling. Travel speeds up to 25 mph are provided in either direction through a 4-speed transmission. A separate gearing in a "super low" range is provided for indexing during tamping operations.

The tamping heads are powered by a V-belt drive from the fluid coupling on the engine. The vibrating mechanism is adjustable through an eccentrically weighted shaft to provide light or very heavy vibration. The eccentricity of these shaft weights can be varied from a minimum of ⅛ in to a maximum of about ¾ in. The weights are attached



Automatic gang tamper.

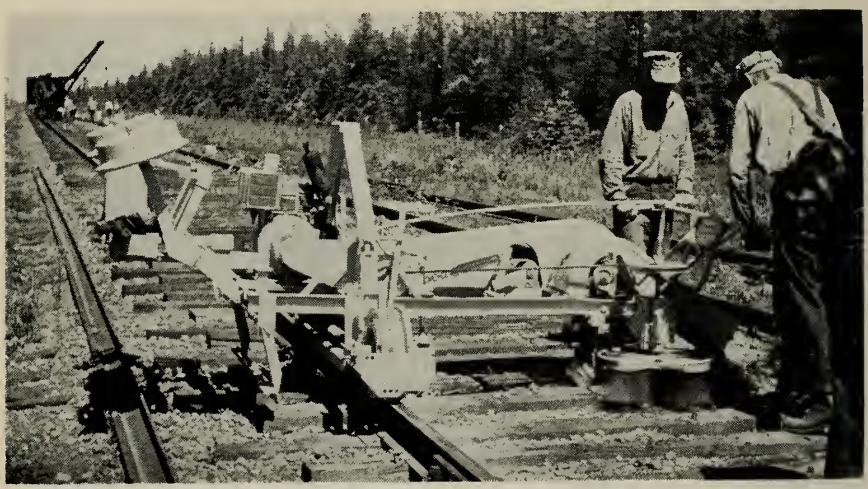
to the shaft by a spring-loaded horseshoe collar which holds the weight in place when the shaft is idle or rotating very slowly. As the speed of the shaft is increased, the weight moves outward under the effect of centrifugal force until it reaches the desired eccentricity as determined by the previously set spring adjustment.

Automatic cycling of the tamping operation is controlled by a 12-v electrical system through 4 banks of relays. The first three banks control the first, second and third insertion of the tamping head and the time of vibration before the head is lifted. The fourth bank controls the final lift of the head and then energizes an electro-magnetic clutch which starts the index movement to the next tie. The second and third control banks may be bypassed, if desired, so that either one, two or three insertions of the tamping head may be selected.

Control of the machine is almost entirely by push button. One button starts the automatic tamping cycle. A second button controls the indexing by spotting the machine over the next tie to be tamped. The machine may be operated by manual push button to eliminate the automatic cycle if so desired.

Ballast Router

Announcement has been made of a new ballast router designed for use in rail-renewal operations. The machine is operated by a crew of two men. It removes and conveys high ballast from the cribs to the side of the track and sweeps the ties ahead of the adzers. Routing of ballast is accomplished with an endless chain fitted with steel



Ballast router.

digging buckets. This chain cuts a trench in the tie cribs, which pitches downward and outward from the center of the track to improve drainage. It is said that only enough ballast is removed to expose the tie and permit sufficient adzing. A rotary broom sweeps the tie clean.

The machine is powered by an 8½-hp gasoline engine which drives the digging chain and broom through a fluid coupling and a V-belt drive.

Diaphragm Pump

A portable diaphragm pump with a variable-speed, rubber-cushioned, vertical-stroke plunger, which is said to be applicable to jobs ranging from dewatering to pumping sludge, is now available. It is reported that excellent priming characteristics make it well suited to applications involving high-suction lifts, seepage control or small wellpoint dewatering jobs. The pump has a standard plunger stroke of 3 in, which is adjustable to 2¾ in. The pump body, valve housing, gear case and frame are of aluminum. The mechanical components and engine are sized to provide operation at maximum capacity with heads up to 40 ft. The suction and discharge connections are 3 in, bushed in 2 in, so that the pump may be used as either a 2-in or 3-in pump. It is mounted on rubber-tired wheels and is equipped with an extension handle for movement from place to place. The operating weight of the pump is 180 lb.

Diesel–Electric Pile Driver

A heavy-duty, diesel-electric, full-revolving pile driver, designed exclusively for pile driving service, has been announced. This machine, equipped with power-battering leaders 50-ft long which will carry a maximum leader load of 26,000 lb, has a reach of 34 ft 1 in from the center of rotation and 20 ft 6 in ahead of the front axle. The leaders will provide a maximum batter of 3 in per ft.

The pile driver, which weighs 211,000 lb in full-operating rig, is powered by 2 diesel engines with a combined horsepower of 385. Each engine drives a traction generator which, in turn, powers travel motors mounted on each of the 6½-in by 12-in trucks. Locomotive gear-reduction cases have a built-in disengaging mechanism which can be used when the pile driver is to be transported in a train. The unit has a top travel speed of 20 mph and a maximum drawbar pull of 21,000 lb. It has been designed to haul its own work train and is equipped with air brakes for braking both the driver and the cars it is hauling.

The machine is equipped with a steam-operated pile hammer which is fired by a 115-hp steam generator with a capacity of 4000 lb of steam per hour. The unit carries water tanks of 600-gal capacity for supplying the steam generator and a fuel oil tank of 275-gal capacity.

Dual Spike Driver

A new machine that drives two track spikes simultaneously has been developed by a manufacturer. In operation, one man on a spike carriage distributes the spikes directly from the keg by placing them loosely in the spike holes of the tie plate. The new driver, operated by one man, positions the spikes automatically with the aid of two magnetized positioners mounted on the machine. These raise the spikes to a vertical position directly in line with two heavy-duty pneumatic hammers also mounted on the machine. An independent 105-cu ft per min air compressor is required to supply air to this machine.

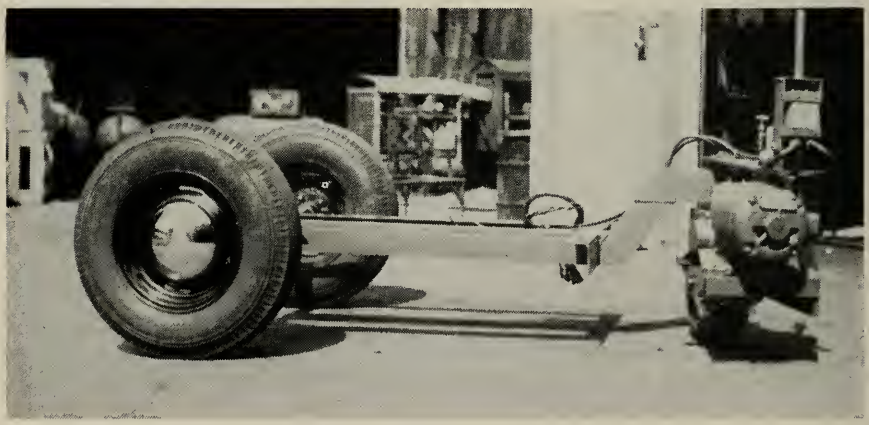
The exact positioning for driving is done by the operator who uses one spike as a guide. Operation of a single control handle then releases the pneumatic hammers driving the spikes. Release of the control handle returns the hammers to non-driving position for movement to the next set of spikes.

The machine is equipped with rubber-tired outrigger wheels which permit one man to remove it from track in wheelbarrow fashion.

Electrically Driven Undercarriage

Announcement has been made of a heavy- welded-steel chassis, tricycle mounted on rubber-tired wheels and driven by a ¾-hp gearhead, extra-heavy-duty, direct-current

Dual spike driver.



Electrically driven undercarriage.

electric motor through a sprocket and chain drive to one of the rear wheels, designed for the transportation of arc-welding machines. This undercarriage is 51 in wide, 103 in long and has a height of 23 in. It weighs 500 lb. Current for the operation of the drive motor is supplied by the welding generator. It is reported that the control settings of the welding machine are not affected by the operation of the undercarriage nor does the operation of the undercarriage affect the welding machine. The equipment may be operated at high or low speed (not to exceed 3 mph). Controls are through a reversing switch with a mechanical interlock. Twisting a rubber-gripped steering handle which is clearly marked for direction, operates this reversing switch.

Hydraulic Personnel Lift

A mobile, hydraulically-operated personnel lift which is reported to facilitate the painting, inspection and maintenance of buildings, tanks, bridges, catenary towers and other overhead facilities, is now available. The unit may be equipped with boom lengths

Hydraulic personnel lift.

of 24 to 100 ft, and is designed to handle a working load of 500 lb. If necessary the boom may be insulated to any specification for working around high-tension wires.

The equipment is designed for mounting on the rear of a 1-ton truck for working outside, or on a fork-lift truck if used indoors. When truck mounted, it has an over-the-road traveling height of 9 ft 4 in. The equipment consists of a hinged boom which supports a working platform. This boom is, in turn, hinged to a supporting pedestal which is equipped with three outriggers, equipped with rubber-tired wheels, which are extended when the equipment is in operation. It is said that these outriggers may be

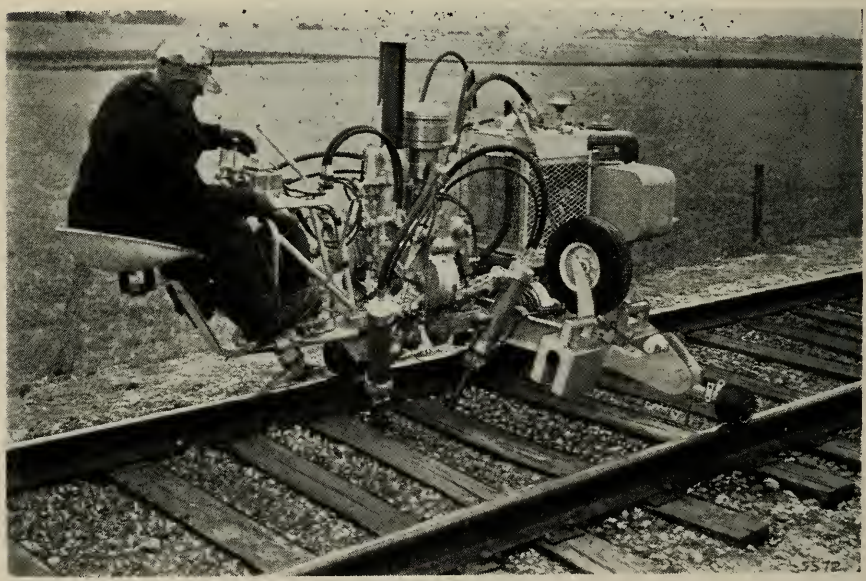
positioned to any ground contour. The truck or other mount acts as the fourth outrigger. The retractable outriggers when extended support approximately 75 percent of the weight of the equipment.

The raising and lowering of the outriggers and movement of the boom vertically are effected through the operation of a series of hydraulic cylinders and pistons. The tower rotates on the pedestal through an angle of 280 deg through the action of a hydraulic motor. Dual controls have been provided for operation. One of these controls is located at ground level and one is located on the platform level. The platform control is of the lever type, which acts through a specially designed valve and directs the travel of the boom in whatever direction the control handle is moved.

The hydraulic pump is of the vane type and develops a maximum pressure of 1500 psi. It has a reservoir capacity of 35 gal. This hydraulic pump is powered with a 6-hp gasoline engine. The unit is arranged so that optional power may be supplied by means of an electric or air motor should such operation be desirable in hazardous or other locations. Set-up time of this equipment from arrival at the job is reported to be approximately 5 min.

Hydraulic Tamper

A one-man operated, completely hydraulic, 4-unit tie tamper, which is self propelled and has a seat for the driver, has been introduced. In this tamper, one central low-pressure (500 psi) hydraulic pumping unit, with direct-engine drive, delivers approximately 1100 blows per minute to each of 4 tamping guns. This power is supplied from an hydraulic accumulator and is directed to each of the tamping-gun hammers through a specially designed valve. The 4 tamping guns tilt automatically and each tamping gun works independently of the others. The main head can be swiveled by the operator to accommodate crooked ties.



Hydraulic tamper.

Power is supplied from a 15-hp, 4-cycle, air-cooled gasoline engine. The entire tamping mechanism, including the power unit, is rubber mounted. A fluid motor has been provided to propel the machine along the rail and operates through a mechanical positioning clutch arrangement.

Two outboard rubber-tired wheels and a swivel-type drop-down wheel on the outrigger have been provided for removing the machine from the track. A hand-operated hydraulic cylinder has been provided as an aid in raising and pivoting the machine and letting the set-off wheels down to operating position. A power winch operated by a fluid motor has been provided as an aid to small gangs when returning the machine to the track. No prepared set-off location is required.

Vertical and lateral movement of the tamping tools, forward and reverse movement of the entire unit, and operation of the power winch are all handled by one man from a control position at the rear of the machine. The machine weighs 2000 lb and is mounted on flanged wheels and an outrigger support. Off-center positioning of the outrigger is said to permit two machines to operate on opposite rails, thus tamping both ends of a tie simultaneously.

Lightweight Push Car

A new lightweight all-steel push car designed for the transportation of tools and supplies from truck or bus to the work site has been announced. The car can be separated at the center for easy transportation. The resulting two sections may be easily handled and quickly hooked or unhooked when assembling. When separated, each section may be used as a truck seat.

The deck of the car is of heavy-mesh expanded steel. A handle which can be slipped into sockets at either end is supplied for pushing the car. The unit has a load capacity of 2000 lb and weighs 140 lb. Platform size is 48 in by 45 in and height above the rail is 8 in. It is mounted on ball-bearing cast-steel wheels.

Motor-Car Carrier

A highway trailer for carrying track motor cars has been developed. This trailer has a load capacity of 1500 lb, weighs 520 lb, and includes loading ramps, complete hitch,

Motor-car carrier.

safety chains, and tail light with license bracket and wiring. It is provided with dual pneumatic wheels mounted under the frame to provide low center of gravity and minimum overall width. The equipment may be operated over the highway at speeds up to 50 mph.

Portable Spray Gun Outfit

A portable spray outfit for the application of paint, varnish, enamel, lacquer, ceramic slurries, insecticides, liquid waxes, whitewash solutions, and other substances has been announced. This device utilizes a large volume of air to atomize the material to be sprayed, rather than high pressure air. This permits the use of a large nozzle orifice and allows the unit to be used for extremely viscous and colloid suspension materials. Air is provided by a blower which is powered by a 1/6-hp motor operating on a 110-volt line. This unit weighs 7 lb and can be slung from the shoulder by a strap.

The spray gun weighing 2½ lb with its self-contained reservoir, uses one all-purpose nozzle to apply all fluids. The spray can be varied from a ½-in line to a 12-in swath. Two valves, independently adjustable and operated in sequence by a single trigger, control air feed and material feed. It is constructed of reinforced aluminum, and the gun is fitted with an easy grip composition handle.

Pressure Pump for Fire Protection

A new lightweight, positive-displacement pressure pump for fire protection in railroad service has been announced. The new pump operates at pressure from 250 to 300 psi and is said to be usable with salt water or water containing sand or silt. Weighing only 29 lb, the pump features automatic priming and an automatic by-pass adjustable over the complete range of the pump. Capacity is 12 gpm at open discharge, 11 gpm at 250-lb pressure, and 10 gpm at 300-lb pressure. Shut-off pressure is at 320 psi. It is powered by a single-cylinder, air-cooled, two-cycle gasoline engine. The pump is rated 4.5 hp at 4750 rpm. It has a guaranteed suction lift of 26 ft.

Rotary Paint Scraper

A paint scraper that is reported to remove paint at a rate of 100 sq ft per hr—about 4 times as fast as the conventional flame method—has been announced. This device consists of a 1/3-hp electric motor fitted with a carrier strap so that it can be carried over the operator's shoulder. This motor is connected to a rotating cutting head, that runs at 5000 rpm by means of a flexible shaft. The cutting head is equipped with 10 cutters. These cutters may be removed and resharpened. The device has a total weight of 18 lb. The cutting head weighs 6½ lb.

Small Ditching Machine

A small self-contained ditching machine which will dig to depths of 30 to 40 in with either one of two digging booms has been announced. The 30-in boom is equipped with either a 2¼ or 4½-in bucket line, while the 40-in boom is equipped with either a 2½ or 5-in line. It is reported that the switch from one line to the other is a job simple enough for one man to perform in 15 or 20 min.

The bucket line consists of a series of heavy replaceable steel cutters bolted to a steel roller chain. This design is said to provide a low-cost, long-life bucket line that may be considered as expendable and be discarded rather than repaired when it becomes worn.

In operation, backfilling is expedited by placing the spoil at the side of the trench with the aid of a simple system of rotating paddles and plows. These are said to eliminate

Rotary paint scraper.

Small ditching machine.

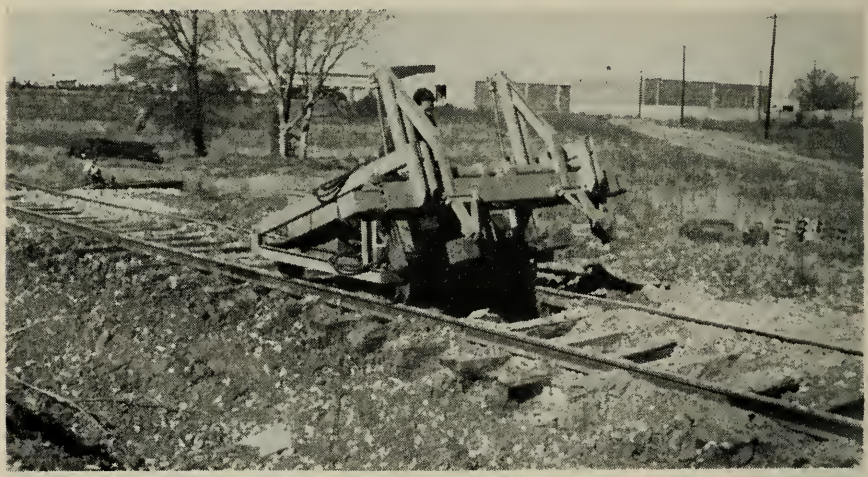
the need of a cross conveyor. The ditcher boom is angled so that the operator can dig under sidewalks and up to foundations.

During the digging operation, the digging and crowding speeds are controlled by means of a hydraulic drive which is said to afford an infinite number of digging speeds between 0 and 40 ft per min. The digging boom can be raised by a mechanical lift which automatically puts the machine into travel position.

This ditcher has an overall widths of 36 in, and weighs 2000 lb. It has an operating travel speed of 240 ft per min (2¾ mph) and can be towed behind a light pick-up truck or passenger car at speeds up to 45 mph with safety.

Tie Bed Cleaner

A machine that scarifies, loosens and cleans the tie bed without raising the track during retimbering operations has been announced. In skeletonizing operations this machine also punches out the "eyes" under the rails. It consists of a working cross-head mounted on a pantograph frame that is riased and lowered by two hydraulic



Tie bed cleaner.

cylinders. Two other cylinders move the head outward, laterally in both directions from the center of the track. The scarifying teeth are attached to this head.

The unit is powered by a 25-hp, 4-cycle, air-cooled gasoline engine which drives a 13-gpm hydraulic pump. Motive power is supplied by an 11-hp hydraulic motor through a 4-speed transmission which provides travel speeds of 3.75 to 15 mph. The machine is one-man operated.

Tie Handler

A tie renewer and inserter for use with tie renewal gangs has been announced. The machine is operated by two men, is hydraulically powered and self propelled. It is fitted with a removable boom when working as a tie remover. It is equipped with pneumatic set off wheels and self storing extension lift pipes for removal from the track.

The machine is powered with a 2-cylinder, air-cooled gasoline engine with a 3¼-in bore and 3¼-in stroke. There are two drives, one for travel and one for operation of

Tie handler (boom removed).

the winch. Each of these drives is powered by a hydraulic motor. Travel drive is through a chain and sprocket on one of the rail wheels. Winch drive is through a flexible-coupled speed reducer and jaw clutch to a roller chain and sprocket on the cable drum.

Tractor-Mounted Air-Drilling Rig

Announcement has been made of a self-propelled drill carrier with crawler-type tracks which is adaptable for use on steep terrain and drilling sites that are unusually rough and rocky. It consists of a hydraulically actuated T-bar mounted on two self-propelled crawler treads, each of which is powered with an air motor. It is reported that the unit will develop sufficient tractive effort to haul an 11,720-lb air compressor up a 10 percent grade.

The T-bar supports a chain feed and a rock drill. It is positioned by a hydraulic hand pump that actuates two lift cylinders. It is said that once the T-bar is positioned and the hydraulic mechanism is locked the outfit is self-equalizing and self-stabilizing, even though one track is tilted up while the other track is tilted down. The T-bar swings through a vertical arc of 86½ deg, which provides an accurate line-up for vertical, angle or toe holes.

Transit Crane

A mobile crane-excavator with 15-ton rated lifting capacity is now being offered by a manufacturer. This crane is powered with a 138-hp gasoline engine. It is mounted on a chassis with 170-in wheelbase equipped with single wheels in the front and tandem duals in the rear. The boom is 30 ft long and is extendable to 70 ft with the insertion of removable inserts. With outriggers set, the 30-ft boom has a capacity of 15 tons at 10-ft radius, and the 70-ft boom has a capacity of 7¼ tons at 20-ft radius. The crane has a heavy-duty, 5-speed transmission and 2-speed auxiliary unit which, when combined, provide 10 forward and 2 reverse speeds. The crane is convertible to ½-yd shovel, dragshovel, clamshell and dragline front ends.

Truck-Mounted Generator

A portable electric generator which is mounted on and secures its power from the truck's engine has been announced. This unit is mounted on the truck bed, directly

Transit crane.

Truck-mounted generator.

behind the cab, and is belt driven from an independent power take-off, geared to the transmission. The belt tension is adjustable. The unit may be removed from the truck when it is not in use. It has an output of 12,500 w at 60 cycles and features a plug-in outlet which supplies alternating current at either 110 or 220-v single phase, and 220-v three phase. It is reported that the unit is capable of supplying power to any electrical equipment which can be normally operated from a 5-kva highline transformer and will handle up to a 10-hp electric motor, depending on its application.

The controls—power take-off knob to engage and disengage the unit and throttle control to obtain any desired rpm up to 2600—are located on the instrument panel of the truck. Generated current is turned on and off by a switch located on the control panel of the generator. The unit is equipped with sealed, lubricated bearings, which are said to require little maintenance. The unit weighs 325 lb and occupies an area 22 in long, 20 in wide, and 20 in high.

IMPROVEMENTS TO EXISTING MACHINES

Crossing Scarifier

A front end attachment which is designed to remove material from between the rails and outward to the tie ends at road crossings has been announcd. This scarifier is designed for application to a ballast regulator. It consists of a rotating drum to which scarifier teeth have been attached.

When mounted on the front end of a ballast regulator, it is powered through a crossing by a cable winch, capable of exerting a 6000-lb pull, which is mechanically

Crossing scarifier.

driven through a power take-off on the ballast regulator. As the machine travels through the crossing, the scarifying teeth on the rotating drum dig into and loosen the crossing material. The machine then travels back through the crossing and plows the loosened material out from between the rails and to the tie ends with the regular plow mounted on the regulator.

Double-Barrel Stud Driver

A powder-actuated tool for driving studs into steel and concrete, which has two interchangeable barrels that are said to be quickly removable and replaceable and which combine to adapt the tool to standard or heavy-duty jobs, has been introduced. The new tool is an improvement over the older model which used the controlled blast of a

32-caliber blank cartridge to hammer nail-like studs through structural materials. The interchangeable barrel feature is reported to permit the use of different "power loads" thus delivering impacts of varying force. This versatility has permitted the design of power loads for proper penetration of alloy-steel studs of specific diameters, lengths and purposes, in various structural materials. The new model thus accommodates 25 types of ¼-in studs in lengths ranging from 1 in to 3¼ in and 12 types of ⅜-in studs in lengths from 1½ to 4¾ in.

The tool is constructed of polished aluminum and hardened steel. Where regulations so require, it can be adjusted for two-handed operation by the removal of a readily accessible set screw. The tool cocks only when depressed against the work and uncocks as soon as pressure is released. Safety guards, both standard or special, are easily fitted to the tool. These guards rotate through 360 deg, and a snap lock, actuated by a thumb lever, is provided on the lower housing.

It is reported that tests conducted by the manufacturer reveal that ⅜-in studs driven into ¾-in steel will resist an average pull-out of 11,600 lb, while an average pull-out of 7100 lb is required to remove similar studs from 3000-lb concrete. Average pull-out for ¼-in studs driven into ⅜-in steel is reported as 3300 lb, and into 3000-lb concrete as 2400 lb.

Hydraulic Sickle Drive

One manufacturer has announced a modification of its on-track weed mower to provide hydraulic power to drive the sickles. This modification eliminates all belts and gearing used in the conventional drive. Pitman-wheel shafts are directly driven by hydraulic motors. The hydraulic system which powers these motors also supplies the power to raise and lower the cutter bars and to tilt the extension beam guide towers.

One centrally located engine, equipped with battery ignition and an electric starter, drives a double vane-type hydraulic pump. Each half of the pump supplies power to one side of the machine. This is said to insure equal sickle speeds regardless of variations in the cutting load.

Power Lift

A power lift has been announced for 8-ft and 13-ft boom derrick cars. This power lift is applicable to the hoisting cable only, the boom cable being manually operated. The lift includes a single-cylinder, air-cooled engine with 3-in bore and 3¼-in stroke, combination pump, reservoir and valve unit, hydraulic motor and worm-type speed reducer. It is applicable to units already in service.

Report on Assignment 4

Improvements to Be Made to Existing Work Equipment

R. E. Berggren (chairman, subcommittee), I. M. Boone, L. E. Conner, Haynie Hornbuckle, M. E. Kerns, W. F. Kohl, Paul Martin, V. W. Oswalt, Sr., R. S. Stephens.

This is a progress report submitted as information. It is a continuation of the progress reports submitted by this committee and found in Vol. 53, 1952, page 396; Vol. 54, 1953, page 666; and Vol. 55, 1954, page 502, and covers changes in work equipment that this committee has found to be practical and desirable.

Track Liner

This machine is designed for lining track in out-of-face surfacing, spot raising, major line improvement programs or lining without raising the track. The actual operation of the machine requires two men, one of whom stands on the ground and manually moves the two lining shoes along a gear rack positioning and locking them in place over the cribs.

Suggested improvement to this machine:

Provide a wire rope or other mechanical device for movement of one or both lining shoes from the operator's position on the machine, eliminating the need of the man on the ground. If only one lining shoe is moved mechanically, the other would be stationary and would require spotting of the machine with the stationary shoe directly over a crib.

Track Gager

This machine is used to gage tie plates during rail laying operations. While the machine holds the plates in position with the runner, a multiple drill head is lowered manually, drilling two anchor holes in the tie through the holes in the plate. Conical-shaped wooden pegs are driven in the holes to hold the plate firm when the rail is laid. One man operates the drills and two men are required to push the machine.

Suggested improvement to this machine:

Provide a flangeless steel wheel to ride the rail and propel the machine by hydraulic motor. Since the weight of the machine keeps the tapered rollers in hard contact to provide accurate gage, there is a limit as to the amount of weight that may be used on the propelling wheel. It is probable that one man will still be required to push the machine.

Track Jack and Tamper

This machine is designed to raise track and tamp both ends of the two ties at the point of raising to hold the track in position for tamping in surfacing operations.

Suggested improvement to this machine:

Enlarge the clamp that grips the rail for raising so that it will clear a 36-in joint bar. This will enable the machine to raise track at the joint, lifting both rail ends instead of one side of the joint lifting only one rail end.

Power Ballast Regulator

This machine is designed for plowing ballast in or out at the tie area and to distribute, shape and dress ballast on the shoulder.

Suggested improvement to this machine:

Revise sprockets on travelling jack shaft so as to have hub extensions on both sides, instead of on one side only, as at present. This lengthened hub should provide greater sprocket strength, better balance and larger bearing seat on shaft. Closer fit on shaft is also recommended.

Spike Puller

This machine is used to pull track spikes when taking up rail. It is mechanically driven by a gasoline engine with a gear reduction. Two sets of tongs are used for the actual pulling, requiring two men, and a third man propels and spots the machine with a handwheel.

Suggested improvements to this machine:

1. Apply self propelling device to be operated by one of the tong men, thereby eliminating the third man.

2. Eliminate the gear reduction and apply a suitable straight pulley or other drive in its place on the engine crankshaft. This is to simplify the machine and reduce maintenance.

Report on Assignment 5

Pneumatic Tires and Tubes

F. L. Horn (chairman, subcommittee), W. F. Kohl, W. E. Kropp, Paul Martin, Harry Mayer, M. C. Taylor.

This report is submitted as information and covers the construction, selection, care, and servicing of pneumatic tires and tubes.

A pneumatic tire assembly mounted on a wheel of a vehicle or machine consists of the tire itself, an air-tight inner tube with a valve assembly for inflation and deflation, and a rim to restrain the tire to its proper shape and attach the tire to the wheel. A properly inflated pneumatic tire assembly functions in such a manner that irregularities in the roadway surface are encompassed by flexing of the tire with minimum vertical displacement of the wheel and minimum transmission of shock to the wheel. When deflected under load the pneumatic tire contacts the roadway surface over a large area, giving it the ability to transmit large tractive forces to the roadway and to carry loads with relatively low unit bearing pressures on the roadway. These features of the pneumatic tires have made possible the high-speed movement of vehicles on highways and the movement of heavy loads over unimproved roadways, both of which are common and important to the railroads.

Materials Used in Tires and Tubes

The materials used in tire and tube construction are rubber compounds and woven fabrics. The rubber compounds are made up of varying proportions of natural rubber, synthetic rubber, and reclaimed rubber, together with additives, to obtain the desired characteristics in the finished tire. The fabrics used are woven from cotton, rayon, or nylon yarn, and are coated with a rubber compound before being used in the tire. The rayon and nylon fabrics are more resistant to the heat built up in a tire in operation than the cotton fabrics, and are being used in increasing quantities.

Construction of Tires

The pneumatic tire is composed of three main parts: (1) the body, built up of plies of rubberized fabric, which absorbs and distributes the load weight and the roadway shocks; (2) the tread, which acts as a wearing surface, protects the fabric against penetration by objects on the roadway surface, and, by means of the configuration of the surface, efficiently transmits tractive forces to the roadway surface; and (3) the bead, which holds the tire in the desired size and shape, and secures the tire on the rim. The tire is built up by laying the desired number of plies or thicknesses of rubberized fabric bands on the cylindrical drum of a tire building machine. The beads, formed as hoops from several turns of rubber-covered high-tensile strength steel wire and wrapped with rubberized fabric strips, are built in as the plies are laid on, one bead near each edge of the fabric bands. The tread rubber, a high-carbon, black, rubber compound shaped to the proper cross section, is then stitched on. The tire is removed from the building drum, and has the shape of an open-end cylinder. The cylindrically shaped tire is placed on end in a pneumatic press, an air bag inserted into the interior,

and the ends of the cylinder compressed so as to bulge out the tread portion of the tire; the tire assuming the approximate shape of the finished tire. The tire containing the air bag is placed in a curing press or mold, steam is admitted to the air bag, and the tire is left in the press to cure; curing time varying from 20 min for small tires to 10 hr for large earthmover tires. The curing process molds the tread design, equalizes stresses within the tires, and vulcanizes the tread rubber. After removal from the press, the tire is ready for inspection and shipment.

Construction of Tubes

The pneumatic tube is made by extruding compounded rubber as a continuous tube, cutting to the proper length, and electrically splicing the cut ends together to form a circular tube. The tube is inflated on forming rings, vulcanized on full-circle molds into the desired shape, inspected for leaks, and prepared for shipment.

Construction of Rims

Rims are manufactured by various metal forming and fastening processes from special steel sections, rolled strip, or plate steel. The design of the rims varies with the design load and characteristics of the tires to be mounted. Rims for light service, and mounting rather flexible tires, are usually of the drop-center type, while rims for heavy service and mounting large, stiff tires are made in two or more pieces, with one rim flange removable for ease in removing and mounting the tires.

Selection of Quality of Tires To Be Used

Only high grade tires capable of a long service life should be used, even though the initial cost of the high-grade tire is considerably more than that of a lower grade tire. The economy of tire use is determined by the cost per mile of service obtained. The low-grade tire, though lower in initial cost, will prove the more expensive on a cost per mile basis because of the shorter service life obtained.

Selection of Tires

The size of the tire, the size of the rim, and the number of plies should be selected to permit the load on the tire to be carried at the recommended inflation pressure. Tables showing loads recommended by the Rubber Manufacturers Association for all sizes of tires and rims are available from most tire dealers. Tire sizes are expressed as two numbers separated by a dash, for example, 6.00–17. The first number designates the cross sectional width; the second the diameter of the rim. Rim sizes are expressed as a number designating the rim width and a letter designates the rim flange height. The size of a tire should be selected so as to provide adequate clearance to all fixed parts of the vehicle or machine to prevent unnecessary chafing.

The sizes of tires on dual wheels should be such that proper clearance between tires can be maintained. Because of the importance of the clearance between tires on dual wheels the spacing of several common sizes of tires and rims, as recommended by the Rubber Manufacturers Association, Inc., is presented in the following table:

Tires Mounted on Advanced Rims

Tire Size	Preferred Rim / Alternate Rim	Maximum Tire Section	Minimum Dual Spacing in Inches Center to Center	
			With Chains	Without Chains
6.50	5.0	7.25	9.0	8.4
7.00	5.5	7.77	9.7	9.0
	5.0	7.57	9.5	8.8
7.50–17	6.0	8.40	10.3	9.6
	5.5	8.20	10.1	9.4
8.25	6.5	9.20	11.2	10.4
	6.0	9.00	11.0	10.2
9.00	7.0	10.10	12.2	11.4
	6.5	9.90	12.0	11.2
10.00	7.5	10.82	13.1	12.2
	7.0	10.62	12.9	12.0
11.00	8.0	11.47	13.8	12.8
	7.5	11.27	13.6	12.6
12.00	8.5	12.30	14.6	13.6
	8.0	12.10	14.4	13.4
13.00	9.0	13.40	15.9	14.9
	8.5	13.20	15.6	14.6
14.00	10.0	14.75	17.3	16.2
	9.0	14.35	16.9	15.8

Note: Overall tire widths of mud and snow type tires may exceed the above maximum overall tire widths by 3 percent to provide for protective side ribs or bars.

The type of service, i.e., on or off the highway, the anticipated roadway conditions, and the travel speed must be considered in selecting the tread design, number of plies, and type of tire. Wheels transmitting large tractive forces, or carrying side thrust, require special tread designs to transmit these forces to the earth. The tire manufacturers have developed many such special tread designs and have detailed information available on them.

The type of cord material contained in the plies of a tire is a factor to be considered in selecting tires. While cotton cord may provide satisfactory service, rayon and nylon cords, with greater strength at operating temperatures, will normally give a longer service life with less cord breakage or distortion, and thereby permit the tire to be recapped one or more times for additional service life.

Selection of Tubes

The high mileage received from tires exhausts the useful life of the tube. Therefore, new tubes of the proper size should be installed in new tires. A tube too small for the tire will be stretched to a thinner section than needed to support the load, resulting in excessive loss of air, increased deterioration, and decreased resistance to chafing and puncture. A tube too large will have creases or folds in it when inflated, resulting in early failure of the tube at the crease and possible damage to the fabric of the tire.

Selection of Rims

The proper selection of rims permits the tire beads to be held in a normal unstrained position, the air volume and consequent road shock absorption to be at a maximum,

the sidewalls to be held straighter and less susceptible to damage, the treads to make full contact with the roadway surface, and the operating temperature to be reduced. All of these factors contribute to increased tire life.

The presently recognized standard rim for automobiles and light industrial tires is the drop-center rim, for trucks and similar applications the "wide-base rim", and for heavy earthmoving equipment, both flat base and tapered bead rims. These rims are furnished as standard on all such new equipment.

The "wide-base rim" for trucks is a relatively new development and merits further discussion. It provides a rim width of approximately 70 percent of the cross section measurement of the tire, has tapered bead seats, and has both flanges designed to provide full support to the beads of the tire. On older vehicles equipped with flat base or other rims the installation of wide-base rims is usually justified by an increase in tire life. Information on this change over may be obtained from most tire dealers.

Rims should be selected to fit the size tire needed to carry the vehicle load. Consideration should be given to the method by which the rim is disassembled for dismounting and mounting tires, and the type most suitable to the available repair facilities selected. Rims on dual wheels should be of the proper size and properly spaced to provide satisfactory clearance between the two tires.

Care and Maintenance of Tires, Tubes, and Rims

After the proper combination of tire, tube, and rim has been selected, the service life of a tire is determined to a very large extent by the care and maintenance practices of the user. Improper inflation, operator abuse, and overloading are the more frequent causes of early failure of tires in railroad service. These early failures can be prevented by adherence to recommended practices by all personnel engaged in operating and servicing pneumatic-tired vehicles and machines.

The operator of a motor vehicle or rubber-tired machine should:

1. Check the weight and distribution of his load to insure that none of the tires are overloaded. Overloading results in excessive flexing, overheating, and breakdown of the cords in the sidewall and shoulder areas of the tire.
2. Check the air pressure in the tires when cool at least once each day by gage and frequently through the day visually. Over inflation results in tread cracking and center tread wear; under inflation in excessive flexing and cord breakdown.
3. Adjust air pressure downward to correspond to the actual load carried. This will permit full contact of tread with roadway surface.
4. Refrain from "bleeding" tires to relieve built up pressure after tire has been used in normal service. Tires are designed to accommodate a temperature and pressure rise when used in accordance with recommended load and air pressure.
5. Operate the vehicle or equipment within the speed range recommended for the load and roadway conditions. Excessive speed builds up excessive heat and air pressure.
6. Refrain from running on a flat or very low tire. Excess flexing results in damage to the tire and tube.
7. Make gentle stops and starts. Quick stops and starts cause excessive tread wear, and may cause flat spots which will continue to grow for the life of the tire.
8. Avoid holes or objects in the roadway at high speeds. Cord breaks and rim damage may result from localized impacts.

9. Periodically inspect all tires on the vehicle for damage and uneven wear, and report to supervisory personnel discrepancies noted. Mechanical irregularities of the vehicle or wheels can cause rapid and uneven tread wear.
10. Check dual-mounted tires to see that they are properly matched and each is carrying its share of the load. The difference between the 2 tires on a dual wheel should not exceed ¾ in. in circumference or ¼ in. in diameter for tires up to 8.25, and 1½ in. in circumference or ½ in. in diameter for sizes 9.00 and larger. The smaller tire should be mounted on the inside position.
11. Keep all lug bolts tight. Wobbling wheels result in excessive and uneven wheel wear.
12. Remove chains as quickly as they are no longer needed. Running with chains on a hard surface results in excessive flexing and damage to the tire.
13. Observe the "feel" of the vehicle at various road speeds for indication of wheels being out of balance. Excessive tread wear results from wheels being unbalanced.
14. Periodically check dual tires for objects lodged between them and remove such objects immediately. Objects lodged between duals will cause chafing damage to both tires.

Shop personnel should be required to make the inspections listed above on all vehicles or machines coming into the shop, to correct mechanical irregularities affecting tire wear as reported by the operator, and also should:

1. Periodically rotate tires from wheel to wheel on the vehicle, thus preventing excessive uneven wear.
2. Use care in dismounting and mounting tires and tubes so as to avoid rim damage, pinching of the tube, or possible personal injury.
3. Thoroughly inspect each tire and tube removed from service to determine the extent of damage, and repair by recommended methods.
4. Clean rims, tires, and tubes thoroughly before mounting.
5. Be sure that tire, tube, rim, lock ring and flap, if used, are of the proper size before mounting.
6. Straighten dented or bent rims before mounting the tire and tube.
7. Report evidence of operator abuse of tires to supervisory personnel.

The use of specially trained personnel as tire inspectors and repairmen is advantageous when a large number of rubber-tired vehicles and machines are in service. They should make periodic inspections of all tires in service, and supervise repair of tires and tubes.

Repair of Tubes

Small holes or breaks in tubes may be repaired by the "hot patch" method successfully. The area affected should be buffed well, cement and patch applied, and the patch cured by heat for 5 to 7 min. Larger holes may require that the damaged portion be cut out and a piece cut from another damaged tube of the same size be spliced in. This operation requires considerable equipment and would not be economical for the smaller sized tubes, but would be economical for large truck and earthmover tubes.

Damaged valve stems may be replaced in tubes economically. The method of replacing varies with the type of stem, but little specialized equipment is required to replace any type.

Repair of Tires

Damaged or worn tires may be repaired or recapped if the damage is not too widespread and the tire body is in good condition. A considerable amount of equipment and well trained employees are necessary to secure satisfactory results. It is questionable whether enough such repairs would be made on most railroads to justify setting up complete tire repair and recapping facilities. However, commercial shops equipped to do such work are numerous and may be easily utilized.

Repairs to localized breaks or punctures are made by removing damaged tire material; cementing a number of plies of fabric over, and a considerable distance around, the damaged area on the interior of the tire; filling the exterior portion of the damaged area with rubber compounds; and curing under heat. Such repairs may not to be too successful where the tire use combines heavy loading and high speeds.

Recapping of sound carcasses presents an opportunity for greatly extending the service life of a tire. Tires should be recapped when worn to a point where at least 1/8 in of rubber remains over the fabric in the center of the tire, this limit being normally reached when the tread design is still discernible.

Three types of recapping are done; top capping by which new tread rubber is applied; full capping by which new rubber is applied to the tread and a portion of the shoulders; and retreading by which a new breaker strip and new rubber are applied to the tread and a large portion of the shoulder. Tires worn to the proper limit may be top capped, while tires somewhat below the limit or containing radial cracks or tread separations may be full capped or retreaded.

The tire to be recapped should be carefully inspected for defects and damage, and minor repairs made. The old rubber is removed from the tire by buffing over the area to be covered by the new rubber. Cement is then applied, and a shaped strip of compounded rubber, called camelback, is pressed securely on the tire carcass. The tire is placed in a mold of the proper size and tread design, and cured for the required time. The tire is removed from the mold, projections of rubber trimmed off, and is ready for mounting.

Liquid-Filled Tires

The use of liquid filled or partially filled tires at low speeds has become quite widespread where additional weight on traction wheels is desired. However, there is considerable disagreement between individual tire companies as to the advantages to be gained from such practice, as well as to the amount of liquid to put in the tires. The percentage of liquid recommended by some tire companies varies from 75 to 100 percent, while others recommend 100 percent air inflation. The primary usage of liquid-filled tires has been on farm tractors and mine shuttle cars. The liquid used is usually a chemical salt solution to prevent freezing.

Tubeless Tires

A very recent development of the tire industry is the tubeless tire. These tires are being installed at present on most new passenger automobiles manufactured and are available for light industrial uses. It is probably only a question of time until a similar tire will be available in larger sizes.

The tubeless tire is constructed in the same manner as the conventional tire except that the tire is made more impervious to the passage of air, and the surface of the bead area is processed so as to insure an air-tight seal between the tire and the rim. The rim is also air tight and the valve stem is seated in the rim. The pressure of the air in the tire

against the side of the tire presses the outer edge of bead against the rim flanges, forming an air-tight seal.

It is reported by the tire manufacturers that the tubeless tire has several advantages over the conventional tire, some of which are:

1. There is less danger of blowout.
2. Puncture by a small object results in a slow leak rather than a quick loss of air pressure.
3. There is no tube to chafe or wear out.
4. The tires run slightly cooler, giving better wearing qualities.
5. Small punctures may be easily repaired without removing the tire from the wheel.

Most of these advantages are derived from their belief that the tube in a conventional tire may not be perfectly fitted to the interior of the tire and rim, chafing and movement of the tube relative to the tire results in additional heat buildup, and the tube, being in tension, tends to increase the size of any perforation.

Detailed Data on Tires, Tubes, and Rims

The scope of this report did not permit inclusion of various detailed information which would be most useful. However, detailed information can be obtained from most tire dealers, the tire manufacturers, and the Rubber Manufacturers Association, Inc.

Report on Assignment 6

Storage Batteries

C. F. Lewis (chairman, subcommittee), C. T. Blume, G. R. Collier, F. L. Horn, J. A. Mann, E. L. Mire, T. M. Pittman, F. E. Short, F. E. Yockey.

This is a final report submitted as information, and is confined primarily to the construction, capabilities, use and maintenance of lead-acid storage batteries.

Inasmuch as the preponderance of modern-day automotive vehicles and work equipment, as well as many items of larger roadway machines, are equipped with complex electrical systems, the construction, care, maintenance and operation of 6-v and 12-v storage batteries are becoming more and more important to the successful and efficient operation of such equipment. Therefore, it has been deemed expedient to submit, for the information of all concerned, a detailed informative report covering these batteries.

NICKEL-CADMIUM STORAGE BATTERIES

As a matter of information, there recently has been placed on the American market a new type of storage battery known as the "nickel-cadmium" battery. The general construction characteristics of this battery are similar to the lead-acid wet storage battery, which is described in detail in another part of this report, with the exception of the active materials used and the number of cells per battery. Basically, the nickel-cadmium battery is an alkaline system using a solution of potassium hydroxide as the electrolyte. The grids of both positive and negative plates consist of sintered carbonyl nickel powder. The active material of the positive plate when charged is nickel oxide and that of the negative plate is cadmium. The EMF of a cell at room temperature is approximately 1.3 v, compared to 2.1 v for lead-acid type batteries.

Each plate of the cell core assembly has as its foundation a screen of nickel wire mesh. This screen is converted into a sheet, or "plaque", by depositing nickel powder in

its meshes by means of a sintering process. Although the plaque is metal, it is in the form of a relative porous structure, and it is the active material electrochemically deposited within the pores which distinguishes between the negative and positive plates. Negative plates are made by electrochemically depositing cadmium hydroxide; positive plates, by depositing nickel hydroxide.

The sintered plates of the cells in nickel-cadmium batteries have relative plane surfaces. Hence, they can be placed uniformly close together, the closeness depending, of course, on the thickness of the separator. These features of construction contribute both to the mechanical strength of the cells and to the low internal electrical resistance.

The electrolyte used is a 30 percent solution, by weight, of potassium hydroxide in distilled water. During charge and discharge of the battery, no overall chemical change in the electrolyte takes place. For this reason there are no appreciable changes in the specific gravity as the state of charge of a cell changes.

Although these batteries are reputed to be superior to the lead-acid wet-type storage batteries, with reference to performance (particularly with regards to extremes of heat and cold), service life (approximately 15 year's expectancy), weight, durability, low maintenance costs, etc., their prohibitive high cost generally precludes their widespread use in privately-owned and commercial automotive vehicles, work equipment and roadway machines. Such a battery would be desirable for installation in equipment and machinery that must be continuously available for instant emergency use, but this committee does not feel that such batteries are practical for general wide-spread, ordinary use.

Therefore, because nearly all automotive vehicles, work equipment, etc., are equipped with lead-acid type wet-cell storage batteries, the remainder of this report will be confined to this type.

LEAD–ACID STORAGE BATTERIES

A lead-acid storage battery is defined as an electro-chemical device for converting stored chemical energy into electrical energy and also for converting electrical energy back into stored chemical energy. These actions are reversible, but the battery does not store up electricity at any time; it can only store chemical energy. The capacity to do so is strictly limited, depending principally upon the amount of available active material and the concentration of the electrolyte.

An automotive-type lead-acid storage battery has three major functions: (1) to provide a source of current for starting, lighting and ignition, (2) to help control the voltage in the electrical system, and (3) to furnish current when the electrical demands exceed the output of the generator.

For the battery to maintain these functions, it is necessary that the current withdrawals be replaced by sufficient current from the generator. If the outgo exceeds the input, the battery will eventually be unable to function as a source of current unless the deficiency is made up by recharging from an outside source.

Automotive-type lead-acid storage batteries always consist of three or more cells connected in series, the voltage for each cell, when fully charged, being approximately 2.1 v, with acid of about 1.280 specific gravity. Therefore, the 6-v battery usually consists of 3 acid-proof compartments and the 12-v battery consists of 6 acid-proof compartments, each containing an element composed of 2 different groups of plates assembled with separator. The first group consists of the negative plates of sponge lead and the second consists of the positive plates of lead peroxide. The electrolyte is a solution of sulphuric acid in water.

Batteries for electrically operated chore boys, high lifts, auto cart cranes, car icers, etc., are, of course, much larger than usual automotive type batteries but are merely multiples of usual battery cells and are constructed primarily the same.

When dealing with batteries, it is always advisable to consider the construction of the main components of a storage battery, which are as follows:

Grids

The plates of a lead-acid storage battery consist of an electrically conducting grid framework in the meshes of which the active materials are incorporated by electro-chemical processes. These grids serve to conduct the current to and from the active materials of the positive and negative plates. An alloy consisting essentially of lead and antimony is used for these grids. The antimony stiffens and strengthens the soft lead and renders the grids less susceptible to corrosion. The presence of antimony also facilitates casting the fine detail of the wire structure of the grids and enables the battery weight to be kept to the minimum.

Positive Plates

Positive plates are filled with lead peroxide active materials. This is a dark brown, crystalline material, which consists of very small grains or particles, disposed so as to provide a high degree of porosity, in order to allow the electrolyte to penetrate the plate freely.

Negative Plates

Negative plates are filled with a porous mass of lead, in spongy form, which the electrolyte can penetrate freely. The active material also contains so-called "expanders", included to prevent the sponge lead from contracting and reverting to a solid state during the life of the battery.

Separators

No positive plate should touch a negative plate or else all the plates in the cell will lose their stored energy. Thin sheets of nonconducting porous material, called separators, must therefore be inserted between the plates. Materials such as chemically treated wood, porous rubber, porous sheets of resin-impregnated fiber, alone, or in combination with sheets of perforated rubber or mats ot glass fibers, are used for this purpose. Separators have ribs on the sides facing the positive plate, to provide greater acid volume next to the plates, for reason of improved efficiency, and to facilitate acid circulation within the cell. The ribs also minimize the area of contact with the positive plate which has a highly oxidizing effect on wood separators. Glass fiber retainer mats, or perforated rubber sheets, are sometimes placed between the positive plate and the separate to retard the loss of active material from the plate and to protect the separator from oxidation.

Element Construction

The positive plates are welded to a post strap, forming a positive group, and the negative plates are welded to a similar post strap, forming a negative group.

The two groups are dove-tailed together and the separators are then inserted between the plates, with the grooved faces of the separators next to the positive plates. These groups, assembled with separators insulating them, are called an element. One element is used per cell. The post straps extend up through the cell cover and provide terminals for connecting one cell to the other. There may be any desired number or size of plates

used in an element, but there is usually one more negative plate than there are positive plates. No matter what the size of the cell, or the number of the plates in the element, a fully charged cell has only a little more than two volts. The battery voltage is the sum of the voltage of the cells.

Electrolyte

Sponge lead and lead peroxide, which fill the respective plates, are referred to as the active materials of the battery. But these materials cannot become active until they are covered by a water solution of sulphuric acid called the electrolyte. The sulphuric acid of the electrolyte supplies the sulphate which combines with each of the plate materials and releases the electrical energy.

The sulphuric acid electrolyte is also the carrier for the electric current inside the battery between the positive and negative plates, through the separators, and the antimony-lead alloy of the grid framework of the plates carries the electric current to and from the active materials to the outside terminals.

The electrolyte of a fully charged battery usually contains about 38 percent sulphuric acid by weight, or about 27 percent by volume. This corresponds to a specific gravity of about 1.280.

Containers

The containers for automotive-type batteries are of a one-piece molded type and are usually made of hard rubber or bituminous composition. These must withstand extremes of heat and cold, as well as mechanical shock, and must be resistant to the absorption of acid. In the bottom of each cell compartment are molded four narrow element rests, or bridges, on which the element sits. When plates are provided with stub feet on their bottom edges, the feet of the positives sit on bridges 1 and 3 and the feet of the negatives sit on bridges 2 and 4. This minimizes the danger of short circuits due to sediment which falls from the plates onto the bridges where the plates sit.

The repeated discharging and charging of a battery will, of course, gradually wear it out so that after a time the active material of the positive plates, which consists of extremely fine grains of lead peroxide, gradually disintegrates and loses physical contact with the plate on which it has been held. This loosened material is free to fall off the plate and deposit in sediment spaces between the bridges at the bottom of each cell. By the time the sediment spaces fill up to the bottom of the element, the life of the cell is usually spent, since the shredded material will gradually form an electrical path or short circuit between the positive and negative plates and will interfere with the charging and retention of charge of the battery. The battery may, of course, fail before this condition occurs for reasons which will be discussed later. Gasoline and oils should be kept away from bituminous composition containers as they will dissolve the bituminous binders.

Cell Covers and Vent Plugs

Cell covers are usually of molded hard rubber and provide an acid tight seal for the two terminal posts which protrude through the cover. Covers also provide a vent opening in which various devices are often located to prevent over filling when rewatering the battery.

Vent plugs of special designs cooperate with the cover vent opening to baffle the gases and the electrolyte splashed and sprayed against the under side of the cover, to prevent loss of acid from the cell. Plugs and openings should be clean at all times.

Cell Connectors

In order to connect the cells of a battery in series, the elements are placed in each cell so that the negative terminal of one cell will be adjacent to the positive terminal of the next cell and so on throughout the battery. Cell connectors are placed over the protruding terminal posts and welded to them to connect the cells in series. Connectors must be heavy enough to carry the high current required for starting, without overheating.

Tapered Terminals

Battery terminals are of special design, being tapered to specified dimensions in accordance with standards agreed upon by the industry, so that all positive and negative cable-clamp terminals will fit any corresponding battery terminal interchangeably. The positive terminal is slightly larger than the negative terminal so as to minimize the danger of installing a battery in reverse.

Sealing Compounds

Sealing compounds are used to form an acid-tight joint between covers and containers. They are blends of specially processed bituminous substances having resistance to flow at high summer temperatures and resistance to cracking at low winter temperatures.

Chemical Action in a Battery

When the battery is connected into a completed electrical circuit the chemical reactions between the active materials in the two kinds of battery plates and the sulphuric acid in the electrolyte cause a flow of electrical current from the battery.

As the discharge continues, dilution of the electrolyte and the accumulation of lead sulphate in the plates eventually bring the reaction to a stop. For this reason, the active materials never are completely exhausted during a discharge. However, at low rates of discharge, the reactions are more complete than at high rates, since more time is available for the materials to come in contact. When the battery can no longer produce the desired current flow it is said to be discharged. It must then be recharged by suitable flow of direct current from some external source before it can be put back into service.

The chemical reactions which go on in the battery cell recharging procedures are essentially the reverse of those which occur during discharge. A discharged battery should never be discarded until it has been determined that it cannot be successfully recharged or unless examination reveals that it has been permanently disabled.

Capacities of Lead–Acid Storage Batteries

The capacity of an automotive-type storage battery depends upon the number and size of plates used per cell, as well as upon the amount of acid present. For example, the average 3-cell (6-v) batteries used in most automotive vehicles, roadway machines, work equipment, and other light and medium class equipment which do not require heavy-duty batteries, are manufactured with either 39, 45, 51 or 57 plates. Therefore, such batteries have 13 plates (7 negative and 6 positive), 15 plates (8 negative and 7 positive), 17 plates (9 negative and 8 positive), or 19 plates (10 negative and 9 positive), respectively, in each of the three cells. The number of plates per cell does not materially affect the voltage of the battery but does govern the active life potential of a battery.

Heavy-duty batteries have more plates per cell, as well as a greater number of square inches of plate area, than the average battery. These heavy-duty batteries are usually installed in equipment which require a battery of greater capacity.

The so-called "long life" batteries are apparently nothing more than the result of natural progress of battery construction and manufacture, primarily accomplished by use of new and improved materials in their construction.

Twelve-volt batteries are usually manufactured with a lesser number of plates per cell (usually 9, 11, or 13) and their service life potential is not rated as high. It should be understood, however, that the total number of square inches of plate area has proportionately as much effect upon service life potential of a battery as does the number of plates in the battery.

It has been the trend of some manufacturers during the past 3 or 4 years to place 12-v electrical systems and 12-v batteries on equipment engineered with complex electrical systems. In other words, the evolution of change in design, with particular reference to the addition of electrically operated assemblies and controls, has steadily decreased the electrical reserve of the 6-v system to the extent that higher and higher capacity generators have been required to handle the growing electrical requirements. Also, newly developed engines, designed for higher compression ratios, horsepower, and performance have been found to require more ignition reserve than it is practical to obtain from a 6-v source. A 12-v system, on the other hand, has been found to provide ample ignition reserve to meet the newest requirements.

Standard Capacity Ratings of Lead–Acid Storage Batteries

The battery industry has arrived at several accepted standards of battery performance which have been incorporated in the standards of the Association of American Battery Manufacturers, the Society of Automotive Engineers, and the United States Government as follows:

A 20-hr rating in amperes indicates the lighting ability of a battery. The fully charged battery is brought to a temperature of 80 deg F and is dicharged at a rate equal to 1/20 of the published 20-hr capacity in ampere-hours. For example, a 6-v battery rated by the manufacturer at 100 amp-hr capacity would be discharged at 1/20 of 100, or at 5 amp, until the terminal voltage falls to 5.25 v. The number of hours required for the discharge, multiplied by the rate of 5 amperes, is the ampere-hour capacity of the battery and its 20-hr rating.

Ratings of 300 amp at 0 deg F indicate the cranking ability of a fully charged battery at low temperatures and are expressed in two ways:

1. By the terminal voltage of a fully charged 6-v battery taken 5 sec after start of a discharge at 300 amp and with initial electrolyte temperatures of 0 deg F.
2. By the number of minutes required for a 6-v battery to reach a terminal voltage of 3.0 v when discharged at 300 amp with an electrolyte temperature of 0 deg F at the start.

Batteries for cranking diesel engines are required to deliver high sustained amperage. Several methods of rating such batteries are employed by various manufacturers. In addition to the ampere hour capacity rating at the 20-hr rate at 80 deg F and the minutes capacity rating at 300 amp at 0 deg F, such batteries are usually rated according to the number of amperes they will deliver for 1.5 min at 0 deg F to an end voltage of 1.0 v per cell.

Diesel cranking batteries are usually constructed with copper insert post straps and cell connectors, better to sustain high amperage delivered during cranking at low temperatures, to reduce the heating of the lead parts, and to minimize the voltage drop in the battery's circuit.

Testing of Lead–Acid Storage Batteries

Batteries should be tested with instruments of unquestionable accuracy.

The hydrometer should be graduated to read from 1.160 specific gravity to 1.320, in graduations of 0.005 specific gravity. The graduated marks should be not less than 1/16 in apart and accurate to 0.002 specific gravity. A battery thermometer should be of the "mercury-in-glass" type and have a scale reading to 125 deg F.

The voltmeter should be accurate within 2 percent of the entire range scale and have a 3-v scale in 0.02-v divisions.

Specific gravity readings are usually taken with a hydrometer and corrected to a temperature of 80 deg F. This is usually done by subtracting 0.004 specific gravity for each 10 deg F below 80 deg F and adding 0.004 for each 10 deg F above 80 deg F.

The open circuit voltage of a fully charged cell is about 2.1 v for electrolyte of about 1.280 specific gravity at 80 deg F.

Size of Batteries Usually Used in Work Equipment and Roadway Machines

The following are, more or less, the standard sizes of batteries used in maintenance of way roadway machines and work equipment:

6-V

AABM Group	*Length, Inches*	*Width, Inches*	*Height, Inches*
1	9	7	9
2	10¼	7	9
2E	19½	4	9
3	11½	7	9
3B	20½	10	9½
4	13	7	9
High Capacity Diesel 12-V			
6D	20½	10	9½

Frequent Causes of Premature Lead–Acid Storage Battery Failure

There are a great many causes for premature storage battery failure. However, the following are among the most common:

1. Defective or improperly set voltage regulators, which will either allow the entire output of the generator to pass through the battery at all times or may undercharge or, perhaps, not charge at all, which will cause the battery to run down.
2. Defective or improperly operating generator, failing to develop enough voltage or current to maintain charge of the battery, causing the battery to run down.
3. Short circuits in ignition or other electrical system, which result in a constant drain upon the battery, causing it to run down.
4. Excessive loads on the battery above the capacity of the generator to supply, and operation of electrical equipment from the battery when the engine or generator is not running.
5. Failure to keep liquid level above the battery plates. This permits the active plate material to oxidize, heat and perhaps slough off. It may cause warping and short circuiting inside the battery.

6. Loose or improperly secured battery terminal connections, causing poor electrical contacts.
7. Excessive corrosion on terminal connections, causing poor electrical contacts.
8. Loose or improperly fastened battery hold-downs causing undue vibration or "bounce" to the battery, which is harmful to the element and container construction.
9. Extreme heat, causing deterioration of the elements and electrolyte within a battery.
10. A battery less than one-half charged may freeze at temperatures around zero. Freezing may crack the container, or damage the plates.
11. Foreign matter finding its way into the battery liquid can cause harmful deposits upon the element plates and retard the action of the electrolyte.
12. Excessive overcharging, caused by a defective regulator, results in heating up the battery, warping, and possible loosening of the material in the plates. The sulphuric acid never reduces because of overcharging but actually reaches maximum strength because of the loss of water, which is reduced by the current, to hydrogen and oxygen.

Care of Lead–Acid Storage Batteries

Although a lead-acid storage battery is a complex piece of equipment, when given adequate care it will give long trouble-free service. Below are a few of the preventive maintenance cares that should be given a storage battery:

1. Maintain battery liquid level to insure that the element plates are covered at all times.
2. Keep battery clean of oils, greases and gasoline, as these agents will cause undue deterioration of the battery container.
3. Keep battery terminals clean and securely fastened to insure proper contacts. A light coating of petroleum jelly or non-oxidizing grease will materially retard corrosion.
4. Safeguard battery from extreme heat or freezing. See Appendix A at the end of this report for the freezing point of batteries with relative specific gravity readings.
5. Safeguard battery from undue vibrations or bounce, which are detrimental to the elements and carrier.
6. Check battery frequently with an approved battery tester to determine its specific gravity reading which, in turn, will reflect the condition of the battery itself. When the specific gravity reading of a battery becomes low the battery should be recharged promptly.
7. Check for cracks or breaks in the battery container, as such cracks or breaks allow the electrolyte to seep out of the battery cells which will cause rapid deterioration of the chemical action upon the plates.
8. Avoid excessive loads on a battery, especially in cold weather, for a battery is only 40 percent efficient at 0 deg F.
9. Frequently check conditions of batteries in storage and, if not protected by a "trickle-charger", charge batteries as often as necessary.
10. Keep open flames away from batteries being charged as the gas given off during such charging operations is highly explosive.

APPENDIX A

The electrolyte of a battery in various stages of charge will start to freeze at the temperatures indicated below:

Specific Gravity Corrected to 80 Deg F	*Freezing Temperature, Degrees Fahrenheit*
1.280	−90
1.250	−62
1.200	−16
1.150	5
1.100	19

The above temperatures indicate the approximate points at which the first ice crystals begin to appear in the solution. The solution does not freeze solid until a lower temperature is reached. Solid freezing of the electrolyte may crack the container and damage the positive plates. An automotive battery is in little danger of damage from freezing, provided it is kept well charged.

Report on Assignment 7

Devices for Warning Forces of Approaching Trains

G. R. Collier (chairman, subcommittee), R. M. Baldock, L. B. Cann, L. E. Conner, H. C. Nordstrom, T. J. Reagan, G. M. Strachan, W. B. Super, T. H. Taylor.

This is a final report, presented as information.

Protecting track gangs against approaching trains is an important factor in carrying out railroad maintenance-of way operations, especially in the case of highly mechanized forces operating with reduced manpower.

The speed of the trains has moved the flagman away from the gang a distance far beyond the limits of a vocal warning to the men. Too, the fallibility of man introduces the possibility that the gang will not be warned in time to clear the track with safety. These factors all point to the need of a device that will provide positive and adequate warning for the track maintenance gangs. Several methods of providing this warning are being tried out on various railroads.

Radio

One road is using radio with the larger gangs. A send-receive set is placed on at least one of the machines with the gang. The foreman is able to communicate with the crews of radio-equipped trains as they approach the gang and also with his flagmen. The flagmen each have a small radio, and contact with the dispatcher is by phone. Thus the foreman has complete train information at all times and can direct the actions of the flagmen in detail.

Each of the roads contacted expressed the opinion that early warning via radio, for the larger gangs, was one of the extra benefits they were anticipating if and when their trains were wholly equipped with radio.

Telephones

The portable field phone that can be hooked on the line wires near the point where the gang is working is used by most roads. Some roads permit the foreman to talk direct to the dispatcher, while on others it is necessary that the information be relayed through an operator at an adjacent way station. Flagmen are generally used to provide physical protection for the gang. However, some roads are depending upon a Form "U" train order given to the train crew to alert it to the presence and location of the gang on the district. Temporary restrictive speed boards are located in advance of the gang to further direct the train crew.

Audio Signals

Various audible signals are used, such as whistles, sirens, klaxons and horns, as a warning to the men to clear the track. The whistles are generally carried by the foremen, look-out or other designated employe. The horns, sirens and klaxons are normally located on one of the machines with the gang and are operated by the machine operator.

One manufacturer now has a device in advanced stages of development that will provide approximately 3500 ft of warning. A transmitter is attached to the two rails about 3500 ft from where the gang is working. This feeds a low frequency current into the track. If there are insulated joints between the transmitter and the gang, a filter circuit is attached across the joint to pass the current. A receiver at the point of work picks up the current and keeps a light burning. As a train approaches the transmitter, the current is shorted out and the receiver turns the light off and sounds a warning bell. A second transmitter and receiver, operating at a different frequency, provide protection from the other direction. This device has been field-tested; however, it is understood that further developmental work must be done before the device is released.

Report on Assignment 8

Care and Operation of Work Equipment in Freezing Weather

J. W. Risk (chairman, subcommittee), C. L. Fero, S. H. Knight, W. E. Kropp, F. H. McKenney, F. Martin, J. E. Reynolds, H. A. Thyng.

This is a final report, submitted as information.

In subzero temperatures, if an engine is not equipped with some type of standby heating equipment, the machine should be placed preferably in a heated building. When placed outdoors, it might appear advantageous to start the engine every 3 hr and warm it up for several minutes. This procedure should be a last resort, however, because it can result in the formation of excessive moisture condensation in the crankcase. Adequate heating temperatures during operation are fairly easy to maintain at low air temperatures by the use of radiator shutters and cooling system thermostats. The maintenance of proper engine temperature is important in order to minimize moisture condensation in the crankcase, obtain proper intake manifold mixture distribution, and to provide sufficiently high battery temperature to allow proper charging.

Starting the Engine

When an engine is in good mechanical and electrical condition, it can be started at low temperatures if high enough cranking speed can be achieved and a flammable air-fuel mixture exists in the cylinders. Cranking speed depends almost entirely on the con-

dition of the storage battery or the hand-cranked starting motor and the viscosity of the lubricating oil. A flammable cylinder charge depends essentially on the volatility of the fuel as indicated by its vapor pressure and distillation characteristics.

The Battery

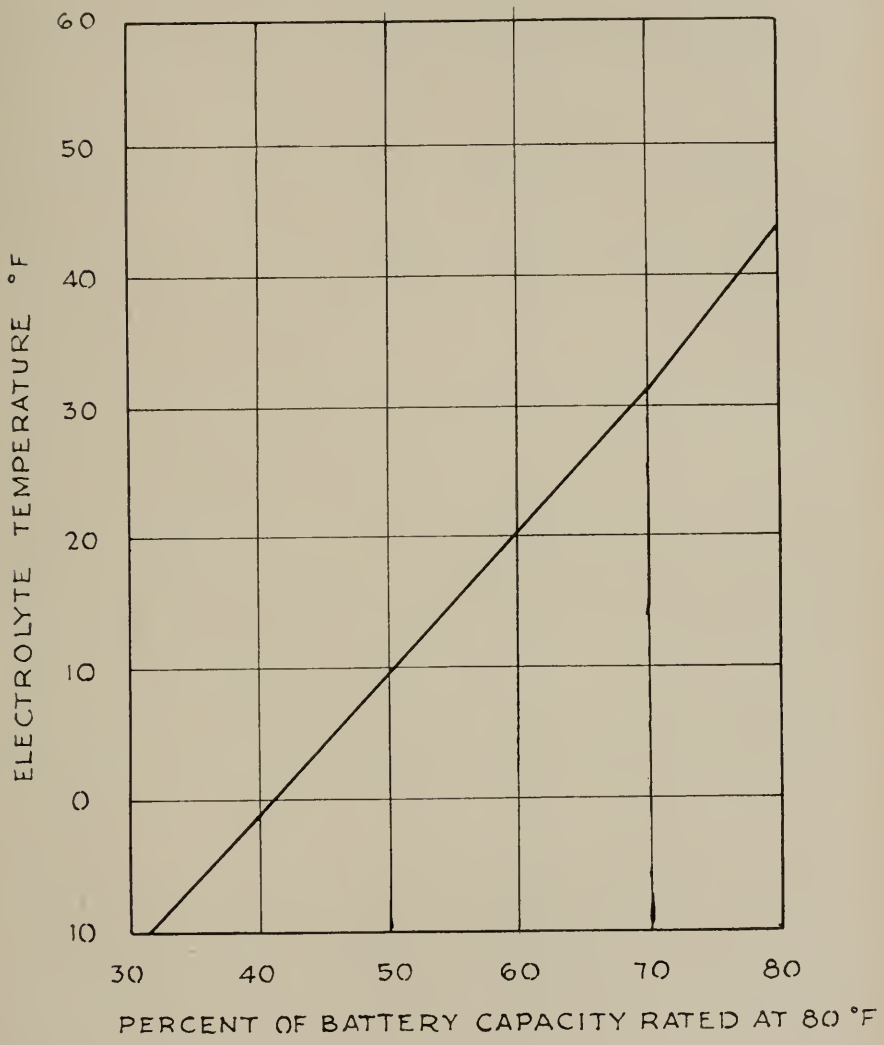
As temperatures drop, the oil films between the pistons and the cylinder walls and between the bearings and their journals become more viscous. This increases the amount of power needed to crank the engine. Under these conditions, available battery capacity becomes extremely important. It is often necessary to use a booster battery at zero or below temperatures. The capacity of a battery is the amount of electrical energy it can deliver for a given length of time. Battery capacity is spoken of in "ampere hours at a 20-hr rate". For instance, a fully charged battery, rated as having a 120 amp-hr capacity, must be capable of delivering electrical energy at the rate of 6 amp for 20 hr with its electrolyte at 80 deg. Its low temperature cranking ability must be such that it can deliver energy at the rate of 300 amp for 4.5 min with its electrolyte temperature at 0 deg before its terminal voltage drops below 3 v for a 6-v battery.

Since the rated capacity of a battery is available only when it is fully charged, it is important to keep it that way. Even when fully charged, the battery capacity decreases with temperature, as shown in Fig. 1. It will be noted that at electrolyte temperatures below 10 deg, less than one-half the rated capacity is available. Another reason for maintenance of full battery charge is to prevent freezing of the electrolyte. Fig. 2 shows that a fully charged battery (1.280 electrolyte specific gravity) is protected against freezing even at temperatures as low as —85 deg. However, when the battery is only one-half charged (about 1.200 specific gravity) its electrolyte will freeze at —20 deg. If the electrolyte freezes, serious damage may be done to the battery. However, if the battery is well charged, damage can be done to the plates by an extended period of cranking without immediate recharging, because the electrolyte spreads more slowly through the battery plate material at low temperatures; in such cases, rapid discharge on the surface of the battery plates, plus the slow diffusion of the electrolyte, can result in the formation of water within the plate material. The water will freeze quickly, and the resulting expansion will loosen the plate material, thus shortening the life of the battery.

Lubricating Oil

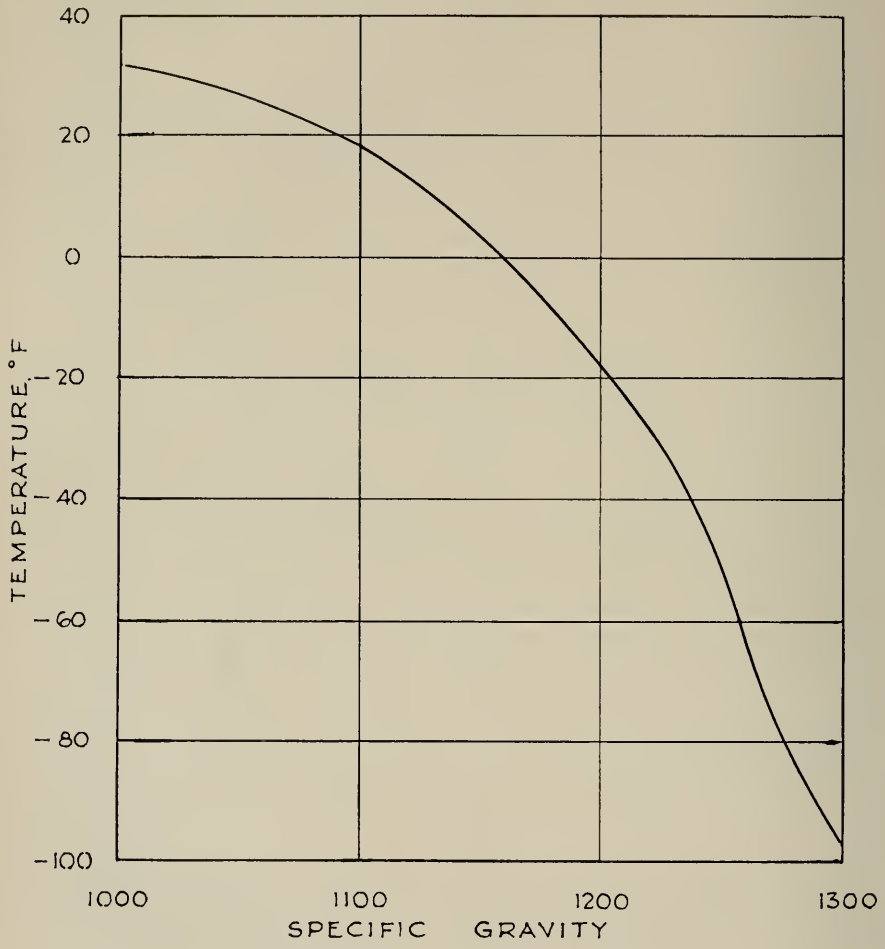
Machinery manufacturers provide excellent lubrication charts specifying grades and lubricants they consider most suitable for their equipment. These charts are extremely useful on jobs where there are not large varieties of equipment, but when there is a large variety of equipment and because manufacturers do recommend in many instances different types and brands of lubricants, it is desirable that these recommendations be consolidated and simplified; otherwise, to meet specified lubricants shown on their charts for a variety of equipment would require more lubricants than could be conveniently handled. As small a number of lubricants as possible, consistent with good lubrication practices, should be provided.

When an oil gets cold, it gets sticky; that is, its viscosity increases. The force needed to move one rubbing surface across another, when both are separated by an oil film, increases as the viscosity of the oil increases. As previously indicated, this oil characteristic has an important bearing on engine cranking speed at low temperatures. There are several methods and units of viscosity measurement. With the Saybolt Universal Viscosimeter a sample of oil maintained at a constant temperature is drained through a precisely made outlet tube into a receiver indexed at a capacity of 60 ml. The length of time



EFFECT OF TEMPERATURE ON BATTERY CAPACITY UNDER CRANKING LOADS.

FIG 1.



FREEZING POINT OF SULPHURIC ACID SOLUTIONS

FIG. 2.

required for the sample to fill the receiver to the index line is measured in seconds, and this value is quoted as the Saybolt viscosity. All engines accumulate small amounts of gasoline or diesel fuel in the crankcase oil, particularly when frequent cold starts are necessary. Unburned portions of the fuel work their way past the piston rings and dilute the crankcase oil, thus reducing its viscosity. Such dilution normally ranges from 2 to 5 percent of the total volume of oil in the crankcase.

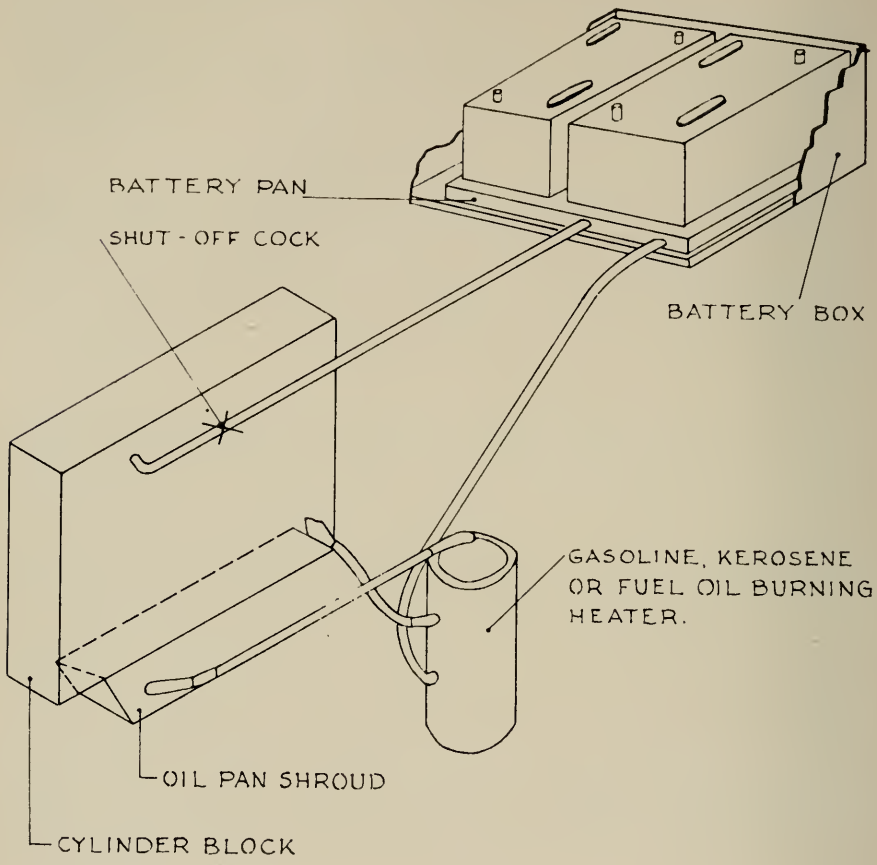
Where temperatures lower than —30 are encountered, it may be necessary to dilute the oil with gasoline or kerosene. The dilution should be added to the engine oil at night before stopping the engine. After adding the dilution the engine should then be run at fast idle for 4 or 5 min so that the diluted oil is circulated throughout the engine. Too long an idling period will "boil off" the dilution if gasoline is used. A rough "rule of thumb" with SAE–10W oil is to add one-half percent of gasoline for each degree Fahrenheit below zero. With a 10-qt crankcase, this would amount to 3 pt of gasoline for temperatures of 30 deg below zero.

Gasoline provides a greater reduction in viscosity for the same percentage dilution than kerosene; it boils off more rapidly, and is more generally available. As the oil temperature rises after engine is started, the gasoline evaporates and the crankcase oil approaches its original viscosity. The heavier dilution (kerosene and solvent naphtha) do not respond as rapidly; hence, they reduce the operating viscosity of the oil for a longer period of time, and this tends to increase the oil consumption. Many tests on a variety of engines indicate that under normal operating conditions, at least one-half of the gasoline dilution would be evaporated from the oil at the end of the first hour, and dilution would reach the normal amount at the end of 3 hr. No detrimental effects on engine wear will occur if gasoline is used as a diluent, if the oil is changed at reasonable intervals. Proper crankcase breather maintenance is very important since a plugged breather vent could build up an explosive mixture within the crankcase. The use of diluents can be avoided if the engine oil is kept warm by an auxiliary source of heat. A gasoline or kerosene burning heater system, such as that shown on Fig. 3, will keep the crankcase oil warm by discharging the hot exhaust gas from the heater into the shroud surrounding the oil pan. Where electrical power is available, strip heaters for oil pan and electric heater in the cooling system (plug-in type) have proven very satisfactory.

Fuel

Adequate engine cranking speed and good mechanical and electrical condition are not all that are required for the starting of an engine at low temperatures. Another necessity is gasoline or fuel oil which will evaporate sufficiently to provide a flammable mixture of fuel vapor and air in the cylinders at the lowest temperature encountered. Here the important gasoline or fuel oil qualities are vapor pressure and distillation characteristics. For every gallon of fuel burned, approximately 1 gal of water is formed in the combustion chamber. Part of this water finds its way into the crankcase as water vapor with the cylinder blow-by. Under adverse conditions, water will condense in the crankcase oil, forming an oil-water emulsion which may become sufficiently viscous to stop the flow of oil through the circulation system. Adequate crankcase ventilation, frequent oil change periods and the maintenance of high oil temperatures will alleviate this problem. For instance, if oil temperatures above 100 deg can be maintained, the water vapor will not condense and will be carried out of the engine through the crankcase ventilation system. Here again, the use of an auxiliary heater system is advantageous.

When operating in temperatures consistently below zero, fuel line freezing may be encountered through moisture condensation in the fuel tank. Filling the fuel tank before



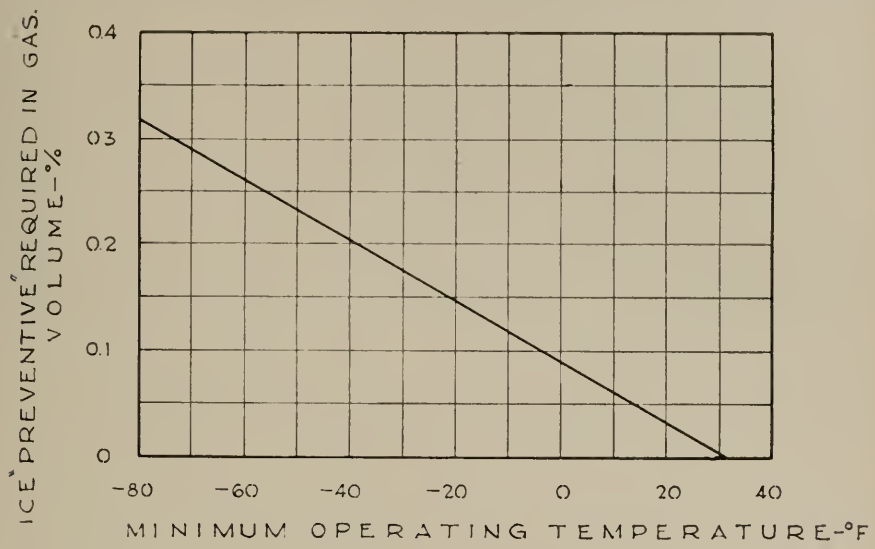
AUXILIARY HEATER SYSTEM

FIG. 3

tying up the machine for the night will help, and the addition of a commercial de-icer fluid or isopropyl alcohol to the fuel will also prevent fuel line freezing. (See Fig. 4).

Starting Fluid

The process of winterizing an engine for easy starting has, up to this point, included selection of the proper fuel, dilution of crankcase oil and the inclusion of an ice



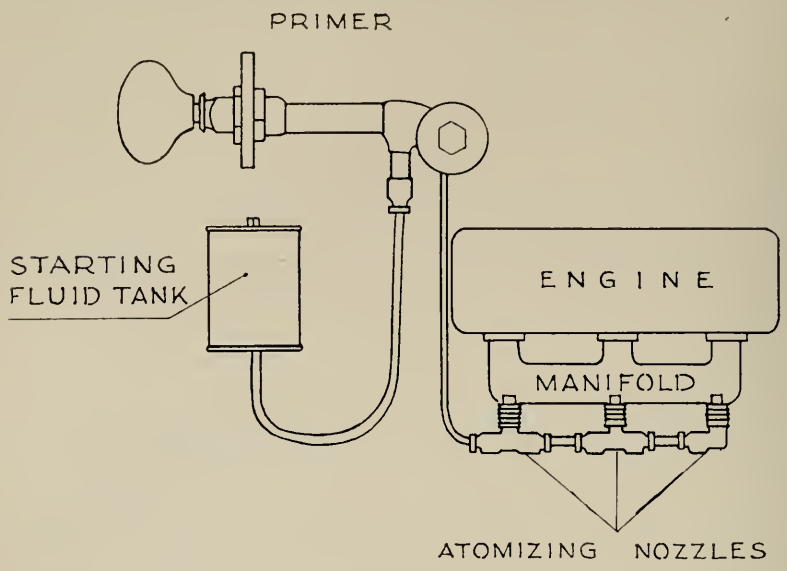
PERCENT "ICE PREVENTIVE" REQUIRED TO PREVENT FREEZING OF WATER IN GASOLINE—WATER-"ICE PREVENTIVE" MIXTURE.

Fig. 4.

preventive in the fuel, but in spite of all this, starting of diesel equipment below 30 deg F and gasoline equipment below zero may be difficult. A starting fluid permits the starting of diesel engines at much lower temperatures than is possible with conventional fuels. For example, attempts to start an engine at — 50 deg F without the assistance of the "starting fluid" failed, whereas, with the starting fluid it was possible to start the engine in 10 sec. This material is injected into the intake manifold during the starting operation by an atomizer with a primary system as shown in Fig. 5. By applying the fluid through the air cleaner, other methods of application such as continuous spray, fly-spray gun, air-pressure atomizer or other similar means can be used with various degrees of success.

Gear Lubricants

Little, if anything, may be said concerning gear lubricants, as their performance qualities have been maintained at a reasonably satisfactory level for a number of years. The major problem is to select the correct viscosity or SAE number for the conditions involved. The most serious problem with improper gear lubricants is the possibility of



PRIMER SYSTEM
FOR INJECTING STARTING FLUID

FIG 5

gear failures due to inadequate lubrication prior to the time the gear becomes warm, if lubricants with too high channel points are used.

Wheel Bearing and Chassis Lubrication

No known devices are available to keep these points warm except where warm storage is available. Where pressure gun application is used, the grease must have sufficient mobility to permit its use in the gun at extreme low temperatures as well as to provide adequate lubrication. Experience has shown that normal greases are not satisfactory under extreme cold conditions; however, special greases have been developed that have adequate low temperature plasticity and proper lubrication properties to make them applicable as all-purpose greases for use in wheel bearings, universal joints, track rollers, drag links, king pins, etc. Some petroleum suppliers have special low temperature grades of specialized products for some of these applications so that use of a compromise product is not required.

Anti-Freeze

In addition to the operating precautions herein recommended, it is necessary, of course, to provide adequate protection of the engine coolant against freezing.

Most anti-freeze compounds are poisonous to some extent; none, however, is so poisonous that it cannot be used in accordance with instructions. Leakage, corrosion or other deficiencies existing in a cooling system should be checked and corrected before installation of any anti-freeze, as such factors can only result in trouble which should not be attributed to the product. Anti-freeze should be drained from the cooling system when the winter is over; it should not be reused during the following winter unless it is known that it is free from contamination and that any corrosion inhibitor present originally has not been weakened or depleted. The suitability of types of anti-freeze base materials may be summarized as follows:

Acceptable types:

The glycols (high boiling point types)
Ethylene glycol
Propylene glycol
The alcohols (low boiling point types)
Meythl (wood) alcohol, or methanol
Ethyl (grain) alcohol, or ethanol
Isopropyl alcohol or isopropanol

Unacceptable types:

The inorganic salts, including:
Calcium chloride
Magnesium chloride
Petroleum distillates
Honey
Sugars

Doubtful types:

Diacetone alcohol

Not Classified:

Glycerine

The above classifications are intended to apply to types, or classes of products and not to any specific proprietary product. Also, the inclusion of any type in the various groupings is not to be interpreted to mean that such type possesses either advantages or disadvantages to the same degree as others listed in the same group.

Reuse of the permanent (ethylene glycol) type of anti-freeze solutions was countenanced, with qualifications, during the war years as a measure for saving critical materials. Major objections to the reuse of saved anti-freeze are inadequate protection for the anticipated temperatures, rusty and dirty condition and exhaustion of corrosion inhibitors.

Anti-freeze protection can be measured with a suitable hydrometer if the type of material is known. Ethyl alcohol, methyl alcohol and ethylene glycol solutions each require a different scale on the hydrometer. If a mixture of two or more base materials has been used, there is no way to determine the anti-freeze protection except by freezing a sample.

Hydraulic System

Modern hydraulic pumps and valves are precisely made. Their close fit is necessary to maintain the high pressures encountered in hydraulic systems. Therefore, to allow hydraulic machinery to operate at its best efficiency, as well as to resist wear and deposit formation, hydraulic systems should be supplied only with high quality oil of the viscosity grade recommended by the equipment manufacturer. Hydraulic systems that must be started up at unusually low temperatures require oils of sufficiently low viscosity and pour point to assure adequate oil feed to the pump while the oil is cold. Hydraulic oils having high viscosity indices give the most assurance of good, low temperature starting characterisitcs, combined with adequate lubrication and the minimum of pump slippage at high temperatures.

Report on Assignment 9

Track Lining Equipment

W. T. Hammond (chairman, subcommittee), L. B. Cann, Herbert Huffman, J. A. Mann, T. J. Reagan, F. E. Short, G. M. Strachan, W. B. Super, H. A. Thyng.

This is a final report, submitted as information.

Multiple tie tamping, ballast handling and tie renewal equipment is being used in increasing numbers for raising and rehabilitating track. The smaller amount of manpower required has, however, made it more difficult to assemble adequate-size gangs to line track currently as it is raised, using lining bars and hand tools.

To meet the need for machinery to perform the necessary track lining as the raising progresses, several types of power track lining equipment have been developed and made available. Basically, all of these types shift track by applying a thrust to either rail, using hydraulic rams or cylinders, actuated by manually or mechanically driven pumps. The various types differ in capacity, type of mounting, method of propulsion and means of anchoring to the roadbed. Two of these liners were described by your committee in its 1954 report on Assignment 3—New Developments in Work Equipment. Since changes and improvements have been made to both, their description is included in this report.

Rail-Mounted Single Unit

Self-propelled and powered by a 13.8-hp, air-cooled, gasoline engine, this machine is a single unit, controllable by one operator as directed by the person sighting the rail.

The mounting is on four single-flanged, split-tread running wheels, so designed that the flanged half of each wheel on the line rail may be moved inward on its axle, creating a minimum obstruction to the view of the gage side of the head. An additional demountable, outside flange is temporarily placed on each of the opposite wheels to prevent derailment while working.

After being positioned at a location where it is desired to throw the track, the unit is clamped to the rails. The actual lining is accomplished by two separate lining shoes, suspended from and movable on a longitudinal gear rack in the upper part of the frame, so that they may be placed over either adjacent or alternate tie cribs. A vertical, double-acting, hydraulic cylinder in the suspension for each shoe not only provides for its raising and lowering, but transfers the weight of the liner from its wheels to the shoes, as well as a portion of the weight of the track to be shifted. Horizontal lining rams, located one at each end of each shoe, apply the desired thrust to either rail at one or two

Rail-mounted track liner.

points simultaneously. Ballast cleats are provided on the bottom of each shoe to resist lateral movement.

Throws as great as 2½ in are claimed to be possible at one setting of the shoes, which may be quickly reset if greater throws are required. The design of this machine permits effective lining of track, except where turnouts, crossing frogs, or other obstructions interfere with the placing of the shoes.

Rail or Crawler-Mounted Single Unit

Controlled by one operator, this hydraulically propelled and actuated liner is powered by a 25-hp air-cooled gasoline engine, driving hydraulic pumps. It is available on either flanged-wheel or crawler mounting.

The design of the flanged-wheel mount permits the operator to support the machine independently of one rail at any location, and to retract hydraulically the running wheels on that side to provide an unobstructed view of the rail. Wheels are retractable on one side of the liner only, and are returned to running position each time before moving to the next point. When using the crawler mounting, the view of both rails is continuously unobstructed.

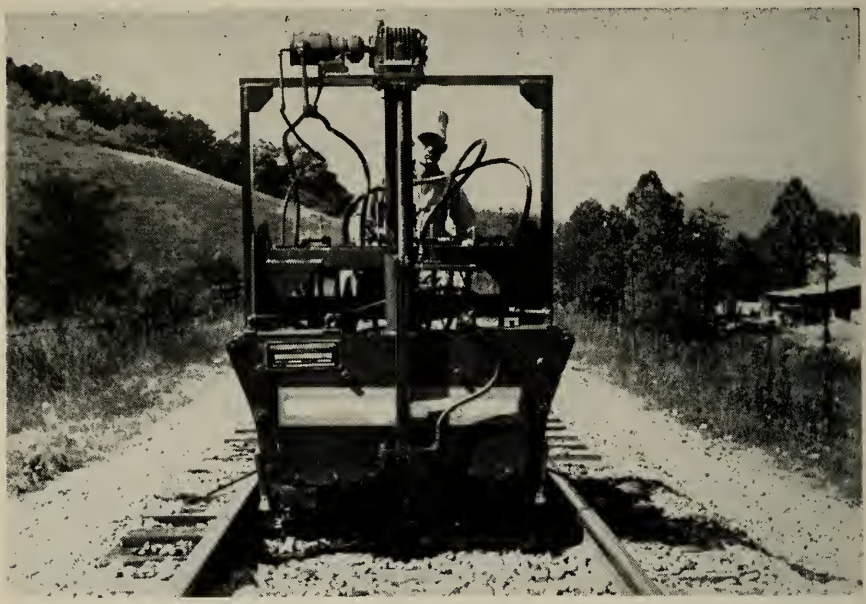
A lining head, mounted on the front of the frame, which is raised or lowered by means of a double-acting hydraulic cylinder, performs the actual lining of the track. Thrust is applied horizontally, at one location, to the base of either rail by hydraulic cylinders located one at each end of the head. Anchorage against lateral movement is obtained by driving a hydraulically rotated spud into the roadbed through the tie crib in the center of the track.

Single throws as great as 6 in are claimed to be absolutely controllable by the operator without causing the track to be raised by the lining operation.

Power Plant with Lining Attachments

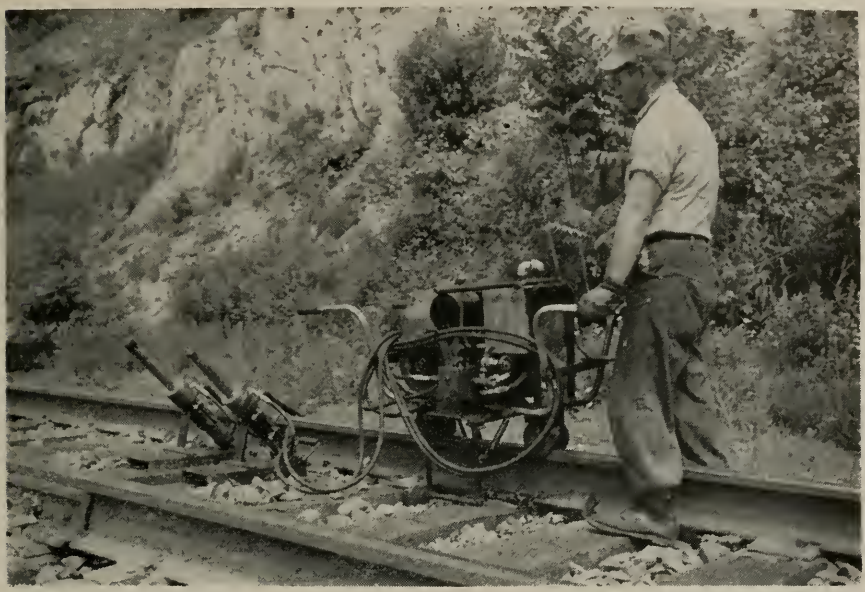
This equipment consists of separate, hydraulic, portable units, which may be arranged in various combinations according to the lining requirements.

The power plant is a hydraulic pump driven by an 8-hp air-cooled, gasoline engine, mounted on a steel base equipped with two small double-flanged track wheels, for support



Front view of crawler-mounted track liner.

Side view of crawler-mounted track liner.



Power plant with lining attachments.

on one rail. An optional off-track wheelbarrow-type mount is available. A small hand-operated hydraulic pump may be substituted for the power plant.

The lining units are small hydraulic rams, having 8-in piston travel, mounted rigidly on steel bases at an angle of approximately 45 deg to the horizontal. Two rams are normally worked with each power plant and are independently connected to it with sufficient hydraulic hose to permit placement in adjacent cribs or separated by several ties.

One man is used to carry and manually place each ram in the tie crib, and an operator manually propels the power unit and controls its pump as throws are being made. The rams depend on the shape of their bases and angle at which they are inserted in tie cribs to resist lateral movement. This combination of units permits lining of turnouts, crossings, and other locations where obstructions prevent the use of larger single-unit liners.

A track-mounted attachment having a single large tilting hydraulic ram, when used instead of the small individual rams, converts this equipment to a single-unit liner. The power plant is placed on special support brackets on the attachment and with minor changes connected to it with short hydraulic hose. One operator manually propels the liner and controls the hydraulically activated rail clamps and ram. A pin-connected shoe at the bottom of the piston provides bearing in the crib, and ballast plates resist lateral movement. The hydraulic ram is tilted in accordance with the direction of the throw desired, and its angle causes the machine to carry a portion of the weight of the track as it is shifted. This unit can effectively line track except where turnouts, crossings or other obstructions interfere with placement of its shoe.

Rail-Mounted Mobile Unit

Being developed, and with at least one machine in active used, is a 16,000-lb single unit liner, hydraulically operated, self-propelled and powered by a 25-hp air-cooled engine.

Actual lining, at two points simultaneously, is accomplished by two lining heads, adjustable to conform to existing tie spacing. Each head contains a hydraulically operated spud for anchorage, as well as horizontal lining rams and vertical double-acting raising cylinders. Equipment includes pneumatic-tired wheels at one end to facilitate towing on the highways.

Report on Assignment 10

Additional Types of Work Equipment Desired

F. L. Etchison (chairman, subcommittee), Edgar Bennett, W. S. Brown, S. E. Haines, W. T. Hammond, Herbert Huffman, E. H. Ness, T. M. Pittman, J. E. Reynolds, M. M. Stansbury.

This is a final report, submitted as information.

Although there are many machines now available for performing a wide variety of maintenance of way work, there are still a great number of maintenance tasks that are being done manually or with hand tools. The object of this report is to acquaint the members of this Association and work equipment manufacturers with the desires of maintenance officers for the development of machines which may effect economies in the performance of those types of work for which machines are not now available.

Maintenance officers of principal railroads have been contacted and the consensus of replies indicates a need for the following equipment:

1. More efficient equipment for distributing and picking up material. If possible this equipment should be able to work either on-track or off-track, as conditions require. Among other things, this equipment should be able to unload and pick up rail, ties, and other track material, set rail in place during rail-laying operations, set other machines off the track when clearing for traffic, and pick up and load metal and miscellaneous material when cleaning yard and car-cleaning tracks.

2. Equipment to apply and remove rail anchors. There are at present many different kinds of rail anchors in use. There is no machinery available for applying or removing these anchors. In order to be practical, equipment to perform this work must be designed so as to be able to handle several of the different types of anchors in use, possibly through the use of interchangeable parts. If possible this equipment should be able to work either on-track or off-track, as conditions require.

3. Equipment to fill old spike holes, either by setting and driving precut wood plugs, or by handling and applying some other suitable material.

4. Equipment to handle and apply rail joints, including the application of grease or other desirable materials at the ends of the rails and the application and tightening of all bolts. Although the joint bars will probably have to be distributed ahead of time as is done at present, provision should be made for the handling of bolts and nut locks, possibly through the use of hoppers.

5. Off-track equipment for handling, setting, and driving track spikes.

6. Equipment to unload cross ties economically from gondolas, flats or other standard cars and distribute them as required along the roadbed close to the location where they will be inserted in the track.

7. Off-track tie renewal equipment. In addition to working on line of road, this equipment should be able to renew ties in yards where the intertrack space is at the minimum and where the level of the ground is almost up to the top of the tie.

8. Equipment for straightening and spacing cross ties uniformly. This equipment to be used primarily in connection with tie renewal program and/or surfacing.

9. Equipment economically and efficiently to distribute ballast when unloading from cars.

10. Equipment to clean and shape ditches in close cuts where clearance is insufficient to accommodate present ditching and grading equipment. This equipment should be able to pick up the material and convey it to the off-side or load it into a car.

11. Equipment to sweep and lubricate switches in interlocking plants and large classification yards.

12. Equipment to lower track more economically.

13. A four-tool multiple off-track spot tamper operated by one man.

14. For use by bridge forces, a small portable apparatus for pulling drift bolts, stringer bolts and boat spikes.

15. Equipment to renew economically bridge ties and the caps and stringers of timber trestles.

16. Equipment for use in jacking culvert pipe through large fills.

The development of new equipment is progressing so rapidly that some of the needs outlined in this report will be fulfilled in the immediate future. Continually, changing work methods will create the need for additional equipment.

Report on Assignment 11

Off-Track Trailers for Housing Maintenance Forces

S. E. Haines (chairman, subcommittee), C. T. Blume, I. M. Boone, W. S. Brown, F. L. Etchison, Jack Largent, C. F. Lewis, C. W. Mitchell, M. C. Taylor.

This is a final report, submitted as information.

The past few years have seen increasing use of highway trailers by the maintenance-of-way departments of many railroads. Trailers may be classified in two categories: first, the self-contained units, and second, those specially designed to perform a specific function in their group. In the first category, trailers are made to accommodate 2 to 4 men. These units have cooking facilities as well as sleeping quarters. In the second category, trailers are made for specific functions, and the group listed below would be typical for a 22-man gang consisting of 1 foreman, 1 cook and 20 laborers. This outfit is flexible and can be varied to suit conditions.

Trailers:

1	for foreman and two men
3	for six men
1	for kitchen (including cook's quarters)
1	for dining room
Total 6	

Trailers need not be elaborately equipped but must be laid out and arranged in a practical manner. Many railroads have provided clean, healthy, comfortable housing for their men by using trailers. Perhaps the most common use for trailers is for housing

large, mechanized gangs. Gangs of specially trained men are kept as a unit and moved from place to place in this way. Often the camp is moved by truck during the day and the equipment moved by night, assuring its readiness for work the following morning.

Trailers are usually wired for a 110-v electrical system and plugged into station facilities as available. If electricity is not locally available, a portable generator supplies the necessary current. The portable generator is usually a complete, separate unit which can be mounted on an accompanying truck, or in the trailer.

Manufacturers offer stoves operated by kerosene, electricity or bottled gas. Likewise, electric, gas or ice refrigerators are available. Trailers are usually heated by space heaters which burn fuel oil or gas.

Showers can be built into trailers, getting their water supply locally or from built-in water tanks. Water heaters are available to insure plenty of hot water. Chemical toilets can be installed and are satisfactory if maintained properly, but may be objectionable from the standpoint of odors. A self-contained septic tank with a marine-type toilet may remove objections to odors. The built-in water storage tanks can be filled as trailers are moved from one location to another.

Ruggedness of construction is essential, as the trailers undergo much harder usage than is encountered in ordinary house trailers. Manufacturers can insulate trailers as necessary according to climatic conditions. Aluminum exteriors requiring no painting are also available.

Some states specify the minimum cubic feet of space per man in a trailer. This limits the number of men who can be housed in any trailer of a given size. It is suggested that any railroad contemplating the use of trailers check the state and local laws regarding movement, length, height, sanitation, and restriction of use of trailers before ordering same. Railroad camp cars are longer than trailers and it is easier to provide more space per man. Trailers, however, are usually more modern than camp cars and provide greater flexibility.

State laws are being revised constantly in regard to permissible length of trailers. Many states have a limitation of 45 ft total, truck plus trailer; therefore, the prevalent size of trailers is from 18 to 22 ft. Trailers are normally limited to 8 ft in width so they can be moved without a permit. Weight is usually not the governing factor as the units are relatively light.

Trucks for hauling trailers from site to site should be of short wheelbase or cab-over-engine type. This model of truck permits a longer trailer length and therefore more room for living quarters.

Some of the suggested advantages of using highway trailers are as follows:

1. More time on the job by reducing travel time to and from work site.
2. No interference with train movements.
3. Elimination of shifting by engine crews which is required with railroad camp cars.
4. No blocking of valuable siding space.
5. Ease of moving gang from place to place.
6. Reportedly less costly than boarding men locally.
7. A means of keeping trained men together as a team rather than hiring men locally and retraining, with a resulting decrease in productivity during training. This is especially true with highly mechanized operations.

Some of the suggested disadvantages of using highway trailers are as follows:

1. Sanitary restrictions.
2. Laws against carrying men in trailers.
3. Parking restrictions.
4. Lack of space for recreation unless a special trailer is provided.
5. Movement of trailers in inclement weather.
6. Licensing.
7. Movement of several trailers a long distance, requiring many trips for one truck or several trucks for one trip.

For the benefit of those who wish to obtain comparative bids the following check list is submitted:

1. Body length
2. Overall length
3. Interior height
4. Overall height
5. Exterior width
6. Axle size:
   - single
   - tandem
7. Wheels:
   - full-drop
   - semi-drop
8. Tires:
   - size
   - ply
9. Spare tire
10. Brakes:
    - two-wheel
    - four-wheel
11. Hitch
12. Safety chains
13. Parking jacks
14. Underframe material
15. Structure material
16. Sub-flooring material
17. Sidewalls—material
18. Riveted or welded construction
19. Section modulus of frame and design stress
20. Area of frame and shear design stress
21. Floor
22. Floor covering
23. Steps
24. Window size
25. Door size
26. Screens
27. Escape hatch
28. Insulation
29. Interior finish

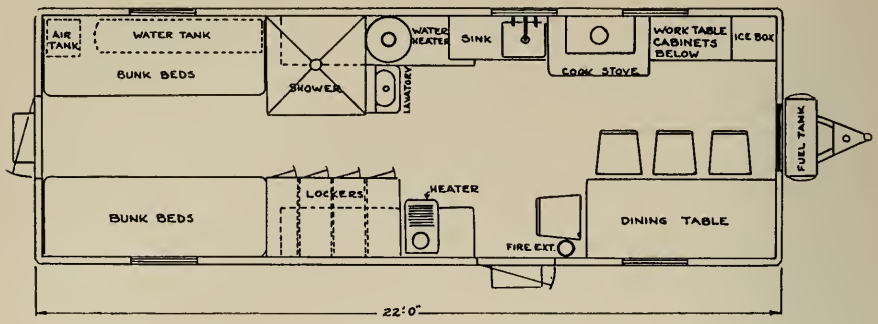


Fig 1 Four Man Trailer

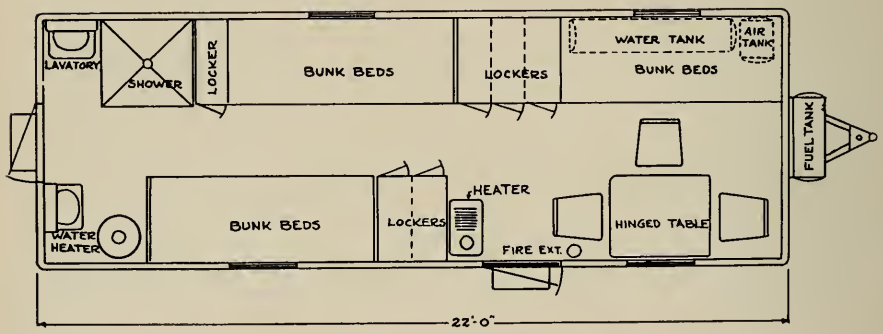


Fig 2 Six Man Bunk Trailer

30. Electrical system: 6 or 12 v
    - clearance lights
    - stop and tail light
    - turn signals
    - reflectors
31. 110-v electrical system
    - fuse box
    - light fixtures
    - outlets
    - wire size in conduit
32. Plumbing—pressure type with reservoir and pump or gravity
33. Hot water tank size
34. Lavatories
35. Mirror
36. Shelf
37. Towel bars
38. Shower
39. Stove

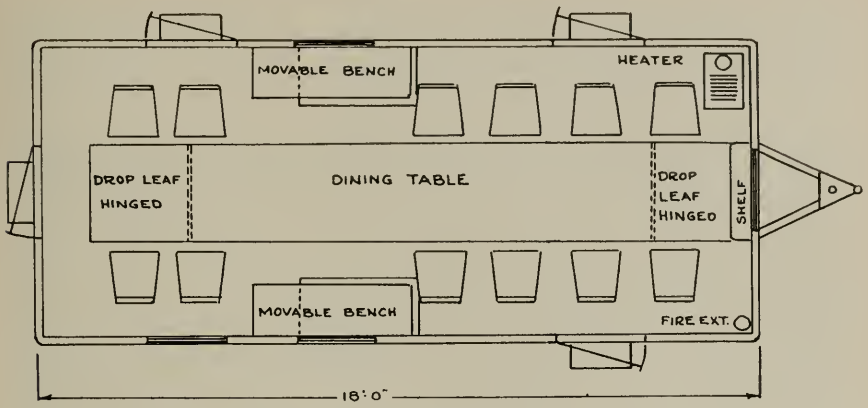


FIG. 3 DINING TRAILER

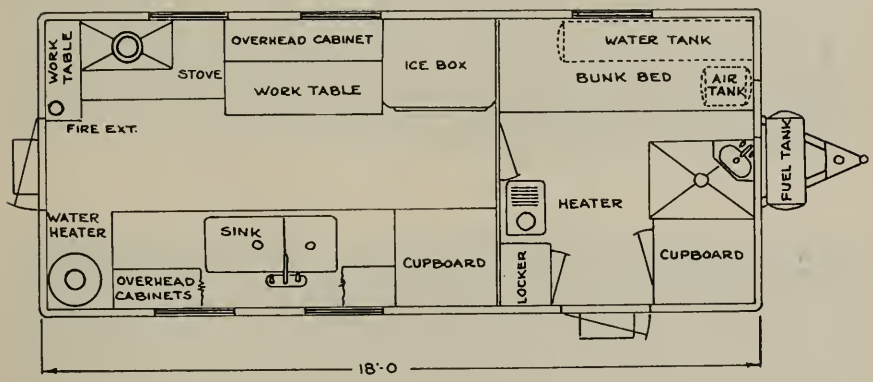


FIG. 4 KITCHEN TRAILER

NOTE: TOILETS NOT SHOWN IN ABOVE PLANS AS OTHER FACILITIES ASSUMED AVAILABLE. FIGS. 1, 2, 3, AND 4 ARE SUBMITTED AS SUGGESTION ONLY AND NOT FOR FINAL DESIGN.

40. Heating system
41. Refrigerator
42. Chairs
43. Tables
44. Bunks
    single
    upper and lower
45. Fire extinguisher
46. Garbage cans
47. Lockers
48. Fans (exhaust and ventilating)

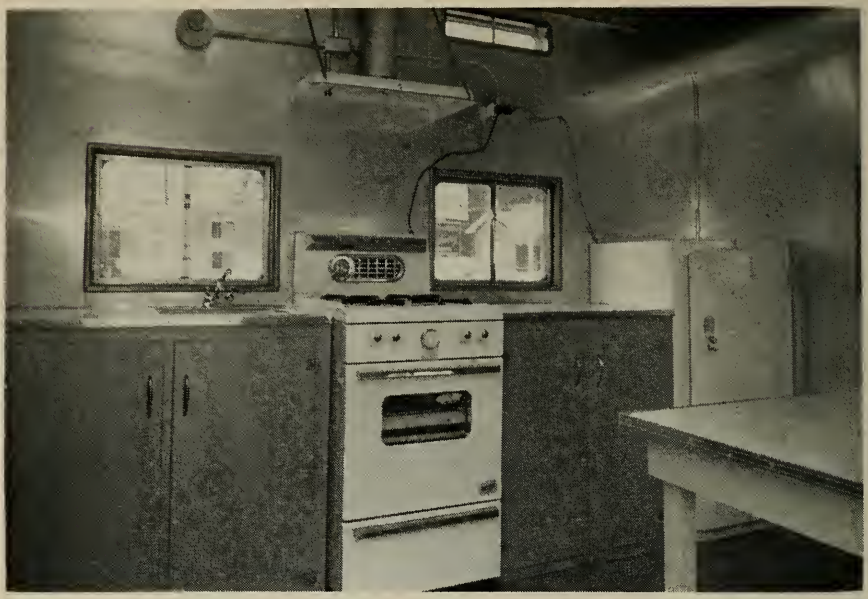
The drawings included as part of this report (Fig. 1 to Fig. 4, incl.) are submitted as suggested examples for arrangement of trailers and can be modified as desirable. Photographs illustrate two types of manufactured trailer which are available, and show the interior arrangement and the kind of facilities provided.

22-ft, 3-man work trailer with two 100-lb propane tanks.

Interior of 3-man trailer showing kitchen and dining area as seen from center of trailer.

Interior of 3-man trailer showing kitchen as seen from front of trailer.

Sleeping compartment of 3-man trailer.

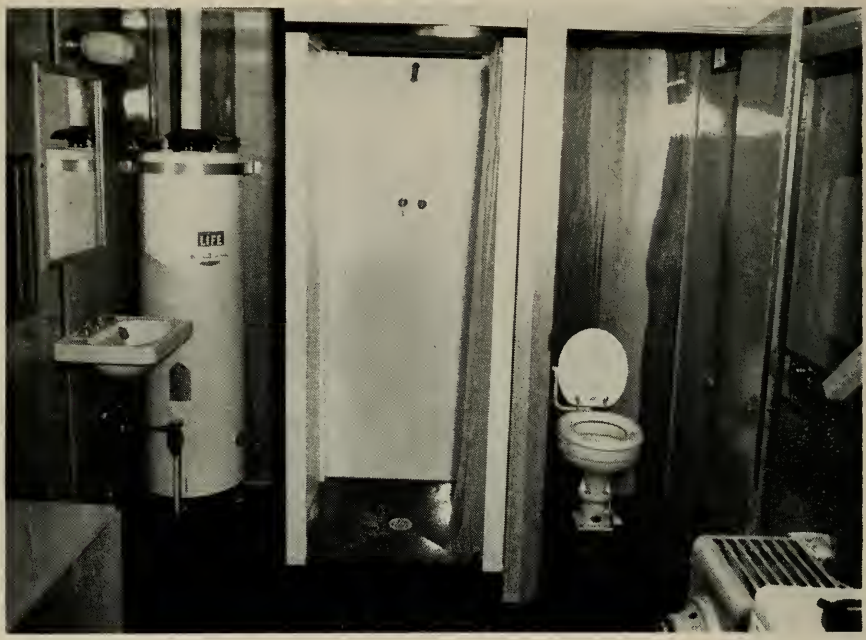


Kitchen facilities of 3-man trailer.

Four-man work trailer.

Kitchen facilities, 4-man trailer.

Sleeping facilities, 4-man trailer.



Wash and toilet facilities, 4-man trailer.

Report of Committee 8—Masonry

M. S. Norris, *Chairman.*

E. A. McLeod,
Vice Chairman,
R. S. Bennett
M. W. Bruns
J. R. Burkey
W. G. Burres
A. E. Cawood
H. C. Charlton
M. Coburn (E)
T. L. Condron (E)*
C. C. Cooke
G. H. Dayett
B. M. Dornblatt
D. H. Dowe
L. P. Drew
G. F. Eberly (E)
W. J. Eney
J. A. Erskine
J. U. Estes
A. B. Fowler
C. W. Gabrio
W. J. Galloway
R. W. Gilmore
J. F. Halpin
J. S. Hancock
R. Hayes
D. E. Hoeffel
W. B. Jackson
A. C. Johnson
E. W. Kieckers
A. P. Kouba
J. A. Lahmer (E)
A. N. Laird
J. F. Leppman
J. C. Lerret
W. C. Love
R. L. Mays
W. L. McDaniel
R. N. Meyer
L. M. Morris
L. H. Needham
J. R. Nutter
R. Owen
D. B. Packard, Jr.
D. Patterson
R. E. Paulson
R. B. Peck
J. E. Peterson
C. B. Porter
H. Posner
L. J. Riekenberg
J. H. Sawyer, Jr.
C. P. Schantz
J. H. Sinneber
D. H. Shoemaker
F. R. Smith
C. H. Splitstone (E)
A. Tedesko
R. A. Ullery
L. E. Vandegrift
N. Van Eenam
K. J. Wagoner
W. R. Wilson
E. P. Wright
Committee

(E) Member Emeritus.
* Died April 12, 1955.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Principles of design of masonry structures, including design of masonry culverts, collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30. Report on "Specifications for Design and Construction of Reinforced Concrete Box Culverts", presented as information with the recommendation that the material be submitted next year for adoption and publication in the Manual ..... page 531

3. Foundations and earth pressures, collaborating with Committees 1, 6, 7, 15 and 30.

   Progress in study, but no report.

5. Tunnel Linings: Design, construction and maintenance, collaborating with Committees 1, 5, 28 and 29.

   Progress in study, but no report.

6. Use of prestressed concrete for railway structures, collaborating with Committee 6.

   Progress in study, but no report.

7. Methods for improving the quality of concrete and mortars, collaborating with Committee 6.

Report on Admixtures for Concrete, presented as information ..... page 539

8. Specifications for the construction and maintenance of masonry structures.

Progress in study, but no report.

10. Methods of construction with precast-concrete structural members, collaborating with Committee 6.

Progress in study, but no report.

THE COMMITTEE ON MASONRY,
M. S. NORRIS, *Chairman.*

AREA Bulletin 526, December 1955.

MEMOIR

Theodore Lincoln Condron

Theodore Lincoln Condron, retired consulting engineer and a Charter Member of the American Railway Engineering Association when it was formed in 1900, died on April 12, 1955. He was born in Washington, D. C., April 16, 1866, the son of Rev. George M. Condron and Abbie (Smith) Condron. He was educated at Rose Polytechnic Institute, Terre Taute, Ind., receiving the degrees: B. S. in 1890, M. S. in 1892, and C. E. in 1918.

In his early career he was employed by the Chicago, Burlington & Quincy on the reconstruction of its bridge over the Mississippi River, followed by a position as draftsman and computer with a consulting firm in Chicago. He was an instructor in the engineering department at Washington University for two years, and was associated with the Pittsburgh Testing Laboratory in Chicago. He entered private consulting practice in 1901 in a partnership, and in 1911 formed the consulting firm of Condron Company. This firm later was succeeded by the consulting firm of Condron & Post, and in both of these firms, Mr. Condron was responsible for the design of a number of large and important buildings and other engineering projects. Mr. Condron retired from active engineering practice in 1947, but continued as a frequent contributor to the technical press and societies until his last illness.

Mr. Condron became a Life Member of the American Railway Engineering Association in 1936. He was an active member of Committee 8—Masonry, for more than 35 years, and contributed greatly to the early progress in concrete work. He also served on Committee 7—Wood Bridges and Trestles, in 1900 and 1901, and on Committee 15—Iron and Steel Structures, from 1902 to 1904. He was honored by the title of Member Emeritus of Committee 8 in 1954. He was a member of the Western Society of Engineers, the American Society of Civil Engineers, the American Society for Testing Materials, and the American Concrete Institute, in all of which he took an active interest.

He is survived by his widow, Grace; two sons, George Tolman and Arnold L. Condron; and a daughter, Mrs. Helen McGuire.

Mr. Condron was an outstanding structural engineer and a true gentleman. He had a fine personality which made many friends for him throughout the country. The members of Committee 8 and his many friends in the AREA will greatly miss him and feel a personal loss in his passing.

Report on Assignment 2

Principles of Design of Masonry Structures, Including Design of Masonry Culverts

Collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30

R. L. Mays (chairman, subcommittee), H. C. Charlton, J. U. Estes, J. S. Hancock, A. P. Kouba, A. N. Laird, J. F. Leppman, J. R. Nutter, D. Patterson, J. H. Shieber, A. Tedesko, L. E. Vandegrift.

Your committee presents as information a tentative draft of Specifications for Design and Construction of Reinforced Concrete Box Culverts, and requests comments and criticisms thereon, with the thought of presenting them next year for adoption and publication in the Manual.

SPECIFICATIONS FOR DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE BOX CULVERTS

A. GENERAL

1. Definition

A box culvert is a structure which forms one or more rectangular openings through an embankment.

2. Types

This specification covers only culverts supported on natural foundations.

Culverts may have one, two, or more openings, but this specification covers only single and double box culverts.

Culverts of this type are used principally for waterways, but may also be used as pedestrian and livestock underpasses, and for other purposes.

3. Size

The size of the opening or openings shall be determined in accordance with the purpose for which the structure is to be used.

The size designation of the opening indicates first the width in feet followed by the height in feet.

4. Field Information

The selection of type and size of culvert depends on specific field conditions. The following information is considered essential for most installations:

a. Drainage area.
b. Run-off characteristics.
c. High water elevation or other limiting conditions.
d. Distance from base of rail to flow line.
e. Minimum distance from base of rail to top of culvert.
f. Embankment slopes and subgrade widths.
g. Number and spacing of tracks.
h. Grade and flow line of floor.
i. Skew angle.
j. Character of the foundation material as determined by exploration methods described in Part 1, Chapter 1.

B. DESIGN PRINCIPLES

1. General

Specifications for Design of Plain and Reinforced Concrete Members as prescribed in Part 2, this Chapter, shall govern except as described herein.

2. Assumptions

The design shall be based on the floor, slab and walls acting as a continuous frame with the positive and negative bending moments determined by an acceptable method of calculation.

3. Design Loads

The following loads shall be used in the design of box culverts supporting track:

a. Dead load.
b. Live load.
c. Impact.

The uniformly distributed loads per square foot to the top of the box for various depths of fill are shown on Fig. 2.

4. Dead Load

The dead load shall consist of the estimated weight of the track, fill and top slab of the structure distributed to the culvert as shown on Fig. 1.

The minimum lateral pressure on the sides of the box shall be based on an assumed earth pressure coefficient of 0.4 and the maximum lateral pressure shall be based on an assumed earth pressure coefficient of 1.0. The lateral pressures on each side of the box shall be assumed uniformly distributed over the entire height, equal and opposite in direction.

5. Live Load

The recommended live load for each track is Cooper E 72. The distribution of the live load to the culvert shall be in accordance with Fig. 1.

No increase in load shall be used for multiple track loadings. The live load will be assumed to increase the lateral pressure on the sides of the box due to a surcharge load in accordance with Fig. 1. The lateral pressure from such surcharge load shall be calculated, using an assumed earth pressure coefficient of 0.4.

6. Impact

To the axle load specified there shall be added impact forces applied at the top of rail and distributed to the top slab and floor as for the live load and equal to the following percentage of the live load:

$$I = \frac{W_{LL}}{W_{LL} + W_{DL}}$$

I = Impact.
W_{LL} = Live load.
W_{DL} = Dead load.

No impact shall be added to the lateral forces on the sides of the box.

7. Other Forces

In general, centrifugal forces, wind force and longitudinal force resulting from starting and stopping of trains need not be considered.

C. DETAILS OF DESIGN

1. General

The drawings shall show in detail all elements of the construction, dimensions, spacing and size of reinforcement, construction and expansion joints, waterproofing, drainage and maximum foundation pressure.

When it is anticipated that a large number of culverts in various sizes and depths of fill will be built, standardization of design and detail is recommended.

Figs. 6 and 7 are typical master drawings for single and double box culverts. Items on thes drawings that are shown blank are for entries to be added to the master drawing for a particular installation. The entries vary with the depth of the culvert and are obtained from standard design sheets. Design details are shown on Fig. 3, while Figs. 4 and 5 are typical standard design sheets for single and double box culverts.

2. Wingwalls

The wingwalls shall be of such slope and length as to retain the embankment and maintain the culvert opening.

The wingwalls may be straight or flared as local conditions require.

3. Barrel and Apron

In general, the same barrel section shall be used throughout, except under very deep fills where a reduced barrel section may be used toward the ends of the box. Consideration should be given to the construction of future tracks.

The length of the apron is determined the same as for the wingwalls.

The floor of the barrel and apron may be sloped toward the center.

Cutoff walls shall be used at inlet and outlet ends of a depth consistent with the field conditions.

D. CONSTRUCTION

1. Joints

If construction joints are used they shall be located as shown on the drawings and formed as prescribed in Part 1, this Chapter.

In long culverts, or culverts under high fills, consideration should be given to the placement of joints to provide for possible vertical and longitudinal movements. If joints are used, the first joint preferably shall be not less than 10 ft from the end of the barrel. Joints should not be placed in regions of maximum load.

Premolded bituminous filler at least ½ in thick may be used at joints.

2. Drainage

The installation of pipe drains in the backfill adjacent to the side walls will not normally be required, but shall be provided in special cases when necessary. Horizontal drain pipes, if used, shall be perforated, shall be not less than 8 in diameter and shall be installed in such a position that they will function properly for ultimate disposal in accordance with the local requirements. Provision shall be made for cleaning.

The surface of the top slab in contact with the backfill may be sloped ¼ in per ft for drainage toward the side walls.

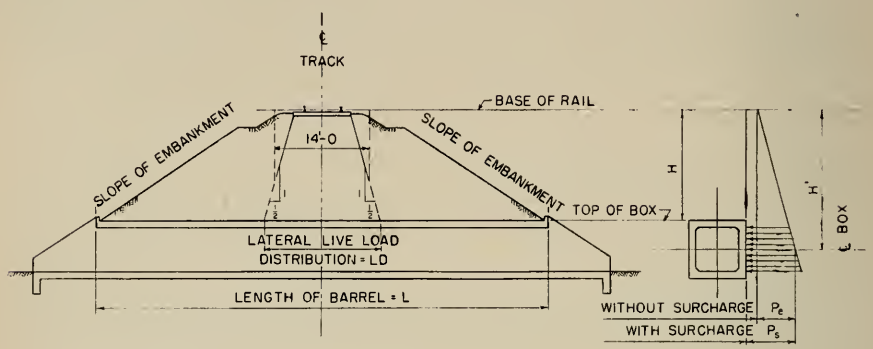
3. Waterproofing or Dampproofing

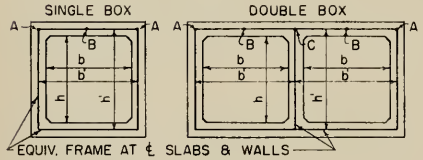
The surfaces in contact with the backfill preferably shall be dampproofed in accordance with the principals contained in Chapter 29.

If culverts are to be used for other than waterways, special provision may be made for waterproofing at joints by the use of a non-corrosive water stop and a waterproofing membrane in accordance with the specifications therefor contained in Chapter 29.

4. Backfilling

The backfill shall be placed alternately on each side of the box and deposited in layers not more than 12 in thick. The layers shall be horizontal or sloping away from the structure, with each layer carefully tamped. The best available material shall be used, and wet or impervious materials shall not be used. Overcompaction must be avoided.





DESIGN EQUATIONS FOR SINGLE BOX:

MAX $M_B = \frac{Wb^2}{24}\left(\frac{1+3K}{1+K}\right) - \frac{P_e h^2}{12}\left(\frac{K}{1+K}\right)$ --- USE MIN VALUE OF P_e

MAX $M_A = \frac{Wb^2}{12}\left(\frac{1}{1+K}\right) + \frac{P_s h^2}{12}\left(\frac{K}{1+K}\right)$ ----- USE MAX VALUE OF P_e OR P_s

$V_A = \frac{Wb}{2}$

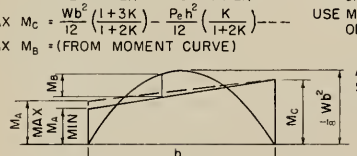
DESIGN EQUATIONS FOR DOUBLE BOX:

MAX $M_A = \frac{Wb^2}{12}\left(\frac{1}{1+2K}\right) + \frac{P_s h^2}{6}\left(\frac{K}{1+2K}\right)$ --- USE MAX VALUE OF P_e OR P_s

MIN $M_A = \frac{Wb^2}{12}\left(\frac{1}{1+2K}\right) + \frac{P_e h^2}{6}\left(\frac{K}{1+2K}\right)$ --- USE MIN VALUE OF P_e

MAX $M_C = \frac{Wb^2}{12}\left(\frac{1+3K}{1+2K}\right) - \frac{P_e h^2}{12}\left(\frac{K}{1+2K}\right)$ --- USE MIN VALUE OF P_e

MAX M_B = (FROM MOMENT CURVE)



ASSUME M_C SAME FOR M_A MAX & M_A MIN

$V_A = \frac{Wb}{4}\left(\frac{2+3K}{1+2K}\right) + \frac{P_s h^2}{4b}\left(\frac{K}{1+2K}\right)$ ---- USE MAX VALUE OF P_e OR P_s

$V_C = \frac{Wb}{4}\left(\frac{2+5K}{1+2K}\right) - \frac{P_e h^2}{4b}\left(\frac{K}{1+2K}\right)$ ---- USE MIN VALUE OF P_e

NOMENCLATURE & DESIGN CONSTANTS

LIVE LOAD = E 72

LOADS ON TOP SLAB:

$W = W_{LL}(I+I) + W_{DL}$ UNIFORM LOAD PER SQ FT

$W_{LL} = \frac{72000}{5 \times LD}$

$W_{DL} = W_e H + \frac{200}{LD} + W_s$

$I(\text{IMPACT}) = \frac{W_{LL}}{W_L + W_{DL}}$

LOADS ON WALLS:

$P_e = k_e W_e H'$ = UNIFORM LOAD PER SQ FT

$P_s = k_s W_e \left(H' + \frac{72000}{5 W_e LD}\right)$ = UNIFORM LOAD PER SQ FT

I_s = MOMENT OF INERTIA OF SLAB - GROSS SECT.

I_w = MOMENT OF INERTIA OF WALL - GROSS SECT.

$S = \frac{I_s}{I_w}$ $R = \frac{b'}{h'}$ $K = \frac{S}{R}$

M_A = MAXIMUM NEGATIVE MOMENT AT CORNER.

M_B = MAXIMUM POSITIVE MOMENT IN SLAB.

M_C = MAXIMUM NEG. MOM. AT CENTER WALL.

V_A = VERTICAL SHEAR AT FACE OF WALL.

V_C = VERTICAL SHEAR AT FACE OF CENTER WALL.

W_e = WEIGHT OF EARTH = 120 LB PER CU FT

W_s = WEIGHT OF SLAB = 150 LB PER CU FT

f_s = 20,000 PSI

f'_c = 3,500 PSI

n = 10

$f_c = 0.45 f'_c$ = 1575 PSI

$k = 0.44$ $j = 0.85$

k_e = 0.4 MIN, 1.0 MAX

k_s = 0.4

$u = 0.08 f'_c$, MAX 280 PSI

LAP MAIN REINFORCEMENT 24 DIAMETERS

LAP TEMPERATURE REINF. 1'-3

$v = 0.03 f'_c$ = 90 PSI MAX WITHOUT WEB REINFORCEMENT.

FIG. 1 DISTRIBUTION OF LOADS & DESIGN EQUATIONS

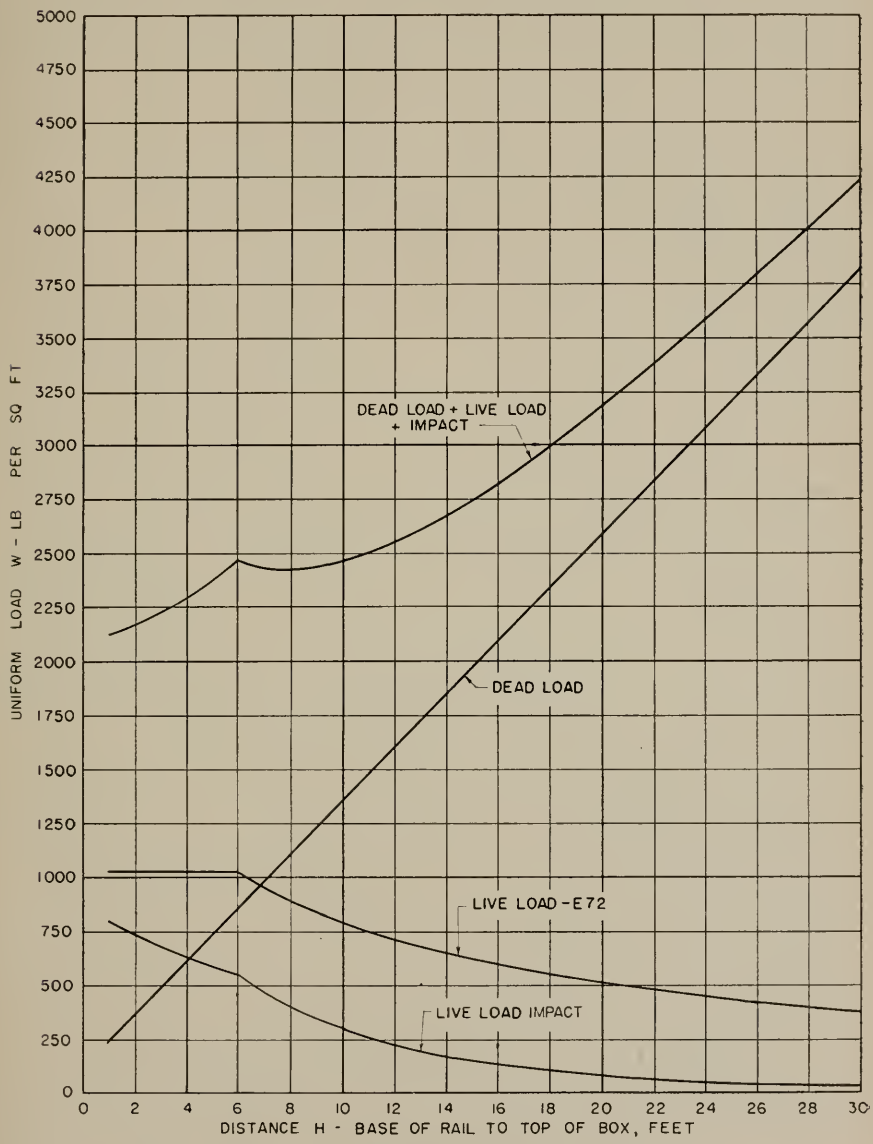
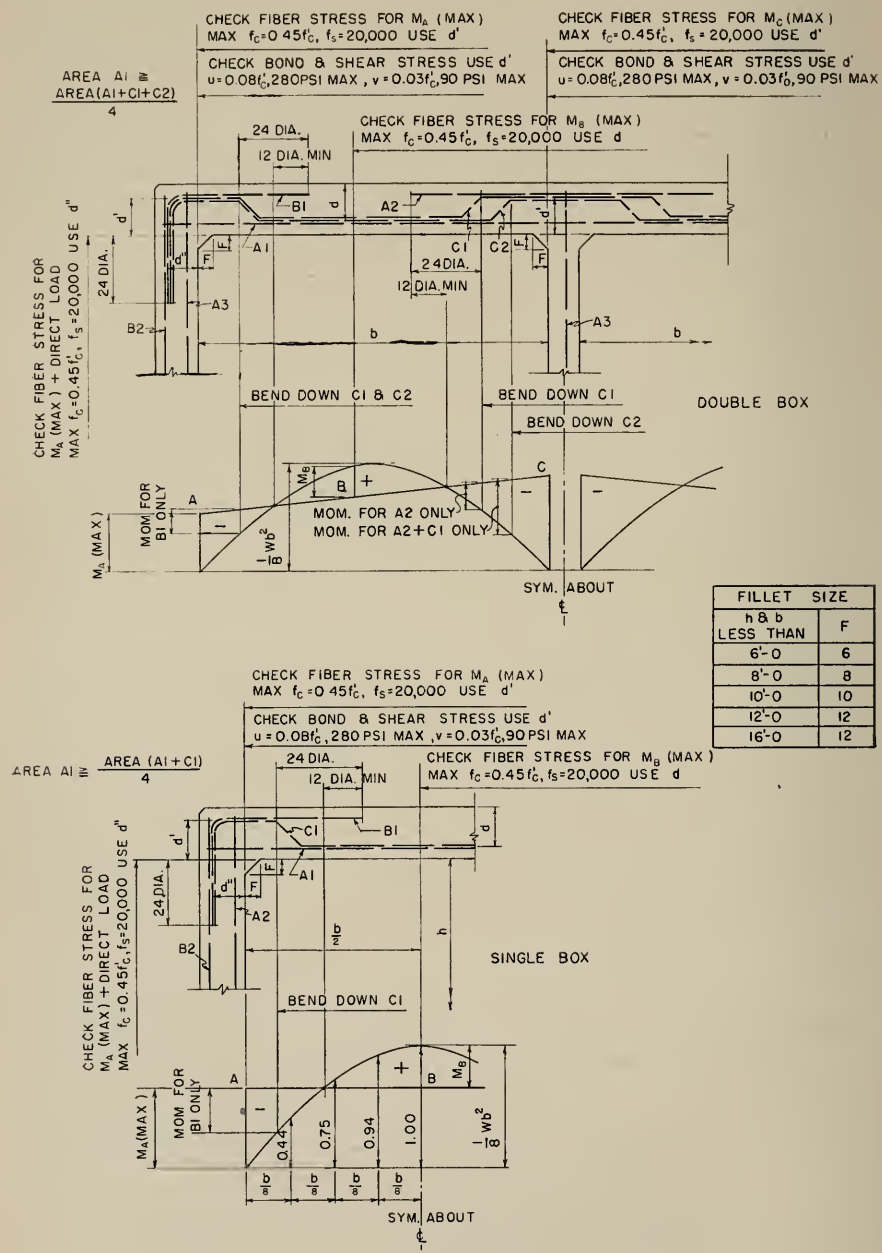
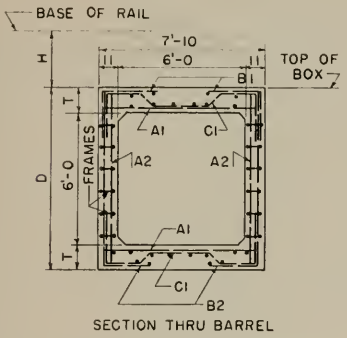


FIG. 2 UNIFORMLY DISTRIBUTED LOAD TO TOP OF BOX



FILLET SIZE	
h & b LESS THAN	F
6'-0	6
8'-0	8
10'-0	10
12'-0	12
16'-0	12

FIG. 3 DESIGN DETAILS



SECTION THRU BARREL

CONCRETE DIMENSIONS		
H	D	T
1'-2 TO 10'-0 INCL.	8'-0	12
10'-1 TO 15'-0 INCL.	8'-2	13
15'-1 TO 20'-0 INCL.	8'-4	14
20'-1 TO 25'-0 INCL.	8'-8	16
25'-1 TO 30'-0 INCL.	8'-10	17

LONGITUDINAL BARS			
LENGTH OF BARREL	NO. OF BARS IN ONE LONG. LINE	LENGTH OF BAR	NO. REQ'D
21'-0 TO 50'-0 INCL.	2	$\frac{L}{2}+6$	40
51'-0 TO 70'-0 INCL	3	$\frac{L}{3}+9$	60
71'-0 TO 100'-0 INCL.	4	$\frac{L}{4}+11$	80
101'-0 TO 135'-0 INCL	6	$\frac{L}{6}+1'-0$	120

QUANTITIES				
H	BARREL		CURBS, APRONS AND WING WALLS	
	CONCRETE CU YD	STEEL LB	CONCRETE CU YD	STEEL LB
1'-2 TO 10'-0 INCL.	1.022 L	111.93L-36	10.83	531
10'-1 TO 15'-0 INCL.	1.067 L	113.31L-36	11.27	531
15'-1 TO 20'-0 INCL.	1.118 L	115.13L-37	11.71	531
20'-1 TO 25'-0 INCL.	1.215 L	122.01L-39	12.15	531
25'-1 TO 30-0 INCL.	1.262 L	123.90L-39	12 58	531

ADD ADDITIONAL STEEL WEIGHTS TO BARREL TOTAL FOR LAPPING OF LONGITUDINAL BARS

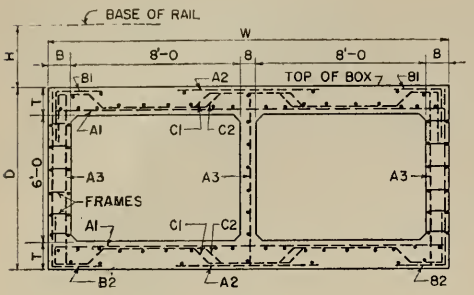
LENGTH OF BARREL	TOTAL STEEL-LB
21'-0 TO 50'-0 INCL	29
51'-0 TO 70'-0 INCL.	66
71'-0 TO 100'-0 INCL.	108
101'-0 TO 135'-0 INCL.	176

NOTES: "L" EQUALS LENGTH OF BARREL IN FEET. NUMBER, DETAIL AND LENGTH OF FRAMES TO BE DETERMINED BY THE DETAILS. "H" EQUALS DISTANCE FROM BASE OF RAIL TO TOP OF BOX.

MAIN REINFORCEMENT					
H	MARK	NO. REQ'D	BAR NO.	SHAPE	LENGTH
1'-2 TO 10'-0 INCL.	A1	2L	5	STRAIGHT	7'-4
	A2	2(L-1)	4	DO.	7'-6
	B1	2L	5	2'-4	4'-8
	B2	2L	5	7'-6	9'-10
	C1	2(L-1)	5	1'-0, 7, 9½, 4'-3, 2'-4, 7'-3 O.-O.	12'-6
10'-1 TO 15'-0 INCL.	A1	2L	5	STRAIGHT	7'-4
	A2	2(L-1)	4	DO.	7'-8
	B1	2L	5	2'-5	4'-10
	B2	2L	5	7'-8	10'-1
	C1	2(L-1)	5	1'-1, 8, 10½, 3'-11, 2'-5, 7'-3 O.-O.	12'-8
15'-1 TO 20'-0 INCL.	A1	2L	5	STRAIGHT	7'-4
	A2	2(L-1)	4	DO.	7'-10
	B1	2L	5	2'-6	5'-0
	B2	2L	5	7'-10	10'-4
	C1	2(L-1)	5	1'-2, 9, 1'-0, 3'-7, 2'-6, 7'-3 O.-O.	12'-11
20'-1 TO 25'-0 INCL.	A1	2L	5	STRAIGHT	7'-4
	A2	2(L-1)	4	DO.	8'-2
	B1	2L	6	2'-7	5'-2
	B2	2L	5	8'-2	10'-9
	C1	2(L 1)	5	11, 1'-3, 3'-9, 2'-7, 7'-3 O.-O.	13'-3
25'-1 TO 30'-0 INCL.	A1	2L	5	STRAIGHT	7'-4
	A2	2(L-1)	4	DO	8'-4
	B1	2L	6	2'-8	5'-4
	B2	2L	5	8'-4	11'-0
	C1	2(L-1)	5	1'-0, 12, 1'-4½, 3'-5, 2'-8, 7'-3 O.-O.	13-6

ALL DIMENSIONS O. TO O.

FIG. 4 RULING DIMENSIONS, REINFORCEMENT DETAILS AND QUANTITIES FOR 6 x 6 SINGLE BOX FOR VARIOUS HEIGHTS OF FILL



SECTION THRU BARREL

CONCRETE DIMENSIONS				
H	D	T	W	B
1'-2 TO 10'-0 INCL	8'-8	16	18'-8	12
10'-1 TO 15'-0 INCL	9'-0	18	18'-10	13
15'-1 TO 20'-0 INCL	9'-4	20	19'-0	14
20'-1 TO 25'-0 INCL	9'-8	22	19'-2	15
25'-1 TO 30'-0 INCL	10'-2	25	19'-4	16

LONGITUDINAL BARS			
LENGTH OF BARREL	NO. OF BARS IN ONE LONG LINE	LENGTH OF BAR	NO. REQ'D
20'-0 TO 30'-0 INCL	1	L-6"	56
31'-0 TO 59'-0 INCL	2	L/2+5"	112
60'-0 TO 88'-0 INCL	3	L/3+8"	168
89'-0 TO 116'-0 INCL	4	L/4+10"	224
117'-0 TO 145'-0 INCL	5	L/5+11"	280

QUANTITIES				
H	BARREL		CURBS, APRONS AND WING WALLS	
	CONCRETE CU YD	STEEL LB	CONCRETE CU YD	STEEL LB
1'-2 TO 10'-0 INCL	2.539L	213.71L-94	16.98	950
10'-1 TO 15'-0 INCL	2.825L	218.06L-95	17.43	950
15'-1 TO 20'-0 INCL	3.115L	224.93L-98	18.00	950
20'-1 TO 25'-0 INCL	3.409L	228.47L-99	18.63	950
25'-1 TO 30'-0 INCL	3827L	23346L-101	19.31	950

CORRECTIONS TO STEEL WEIGHTS IN BARREL FOR LAPPING OF LONGITUDINAL BARS	
LENGTH OF BARREL	TOTAL STEEL-LB
21'-0 TO 30'-0 INCL	SUBTRACT 27
31'-0 TO 59'-0 INCL	ADD 45
60'-0 TO 88'-0 INCL	" 107
89'-0 TO 116'-0 INCL	" 178
117'-0 TO 145'-0 INCL	" 245

NOTES "L" EQUALS LENGTH OF BARREL IN FEET NUMBER, DETAIL AND LENGTH OF FRAMES TO BE DETERMINED BY THE DETAILS. "H" EQUALS DISTANCE FROM BASE OF RAIL TO TOP OF BOX.

MAIN REINFORCEMENT					
H	MARK	NO. REQ'D	BAR NO.	SHAPE	LENGTH
1'-2 TO 10'-0 INCL	A1	2(L-1)	5	STRAIGHT	18'-2
	A2	2(L-1)	8	"	6'-8
	A3	3L	4	"	8'-2
	B1	2(L-1)	4	2'-5	4'-10
	B2	2(L-1)	4	8'-2	10'-7
	C1	L EVEN FT L+1 ODD FT	5	1'-10 C1 1'-4 C2 1'-3 1'-3 5'-2½ C1 5'-5½ C2 18'-1 0-0. 2'-5	23'-9
	C2	L EVEN FT L-1 ODD FT	5		23'-9
10'-1 TO 15'-0 INCL	A1	2(L-1)	5	STRAIGHT	18'-4
	A2	2(L-1)	8	"	6'-8
	A3	3L	4	"	8'-6
	B1	2(L-1)	4	2'-6	5'-0
	B2	2(L-1)	4	8'-6	11'-0
	C1	L EVEN FT L+1 ODD FT	5	1'-10 C1 1'-4 C2 1'-4 1'-3 4'-10½ C1 5'-1½ C2 18'-3 0-0. 2'-6	25'-1
	C2	L EVEN FT L-1 ODD FT	5		25'-1
15'-1 TO 20'-0 INCL	A1	2(L-1)	5	STRAIGHT	18'-6
	A2	2(L-1)	8	"	6'-8
	A3	3L	4	"	8'-10
	B1	2(L-1)	4	3'-0	6'-0
	B2	2(L-1)	4	8'-10	11'-10
	C1	L EVEN FT L+1 ODD FT	5	1'-10 C1 1'-4 C2 1'-6 1'-8 4'-5½ C1 4'-8½ C2 18'-5 0-0. 3'-0	26'-7
	C2	L EVEN FT L-1 ODD FT	5		26'-7
20'-1 TO 25'-0 INCL	A1	2(L-1)	5	STRAIGHT	18'-8
	A2	2(L-1)	8	"	6'-8
	A3	3L	4	"	9'-2
	B1	2(L-1)	4	3'-2	6'-4
	B2	2(L-1)	4	9'-2	12'-4
	C1	L EVEN FT L+1 ODD FT	5	1'-10 C1 1'-4 C2 1'-7 1'-8 4'-1½ C1 4'-4½ C2 18'-7 0-0. 3'-2	27'-5
	C2	L EVEN FT L-1 ODD FT	5		27'-5
25'-1 TO 30'-0 INCL	A1	2(L-1)	5	STRAIGHT	18'-10
	A2	2(L-1)	8	"	6'-8
	A3	3L	4	"	9'-8
	B1	2(L-1)	4	3'-5	6'-10
	B2	2(L-1)	4	9'-8	13'-1
	C1	L EVEN FT L+1 ODD FT	5	1'-10 C1 1'-4 C2 1'-8 1'-9 3'-7½ C1 3'-10½ C2 18'-9 0-0. 3'-5	28'-5
	C2	L EVEN FT L-1 ODD FT	5		28'-5

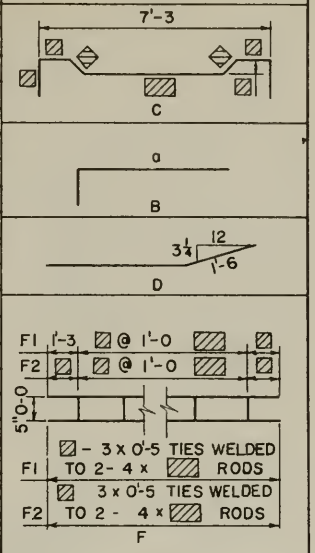
ALL DIMENSIONS O. TO O.

FIG. 5 RULING DIMENSIONS, REINFORCEMENT DETAILS AND QUANTITIES FOR 8 X 6 DOUBLE BOX FOR VARIOUS HEIGHTS OF FILL

BILL OF STEEL REINFORCEMENT

MARK	NO. REQ.	SIZE	LENGTH	LOCATION	a
C1	▨	▨	▨	TOP & BOTTOM SLAB	
B1	▨	▨	▨	TOP CORNERS	
B2	▨	▨	▨	BOTTOM CORNERS	
B3	8	4	7'-9	WING WALLS	6'-6
B4	8	4	7'-1	" "	5'-3
B5	12	4	6'-8	" "	3'-4
B6	8	4	5'-9	" "	2'-2
B7	24	4	4'-10	CUT-OFF WALL	2'-5
D1	8	4	10'-1	WING WALLS	
D2	8	4	7'-5	" "	
D3	4	4	5'-9	" "	
D4	4	4	4'-1	" "	
A1	▨	▨	▨	TOP & BOTTOM SLAB	
A2	▨	4	▨	SIDE WALLS	
A3	8	4	10'-2	WING WALLS	
A4	20	4	7'-4	CURB & APRON	
A5	20	4	9'-10	APRON	
A6	2	4	11'-2	"	
A7	▨	4	▨	LONGITUDINAL BARS	
A8	▨	4	▨	" "	
F1	▨	SEE DETAIL		SIDE WALLS	
F2	▨	" "		" "	

DETAIL



USE 6 DIA. PIN FOR ALL BENDS

955 AREA MANUAL,
CONCRETE, 1952.
BE NOT LESS THAN
ATIO SPECIFIED IN THE AREA MANUAL,
H IT WILL BE SUBJECTED.
ASTM A305 - 53T, INTERMEDIATE

ORM WITH THE DETAIL

CT POSITION.
IMUM LAP OF 1'-3 WHERE

GES. LUMBER USED ON
TO A UNIFORM THICKNESS,
DISMANTLING FORM

ND SO ARRANGED THAT,
R MORE FROM THE

E THE CONCRETE HAS
ICKS, CHISELS OR OTHER
HLY CLEANED OFF, AND

LL BE CAST
ERTICAL BULKHEADS
OINTS ARE USED.
S.
ATED AS SHOWN.
CH SIDE OF BOX, AND

⊖ TOP SLAB AND FLOOR THICKNESS MAY BE REDUCED BY USING STIRRUPS.

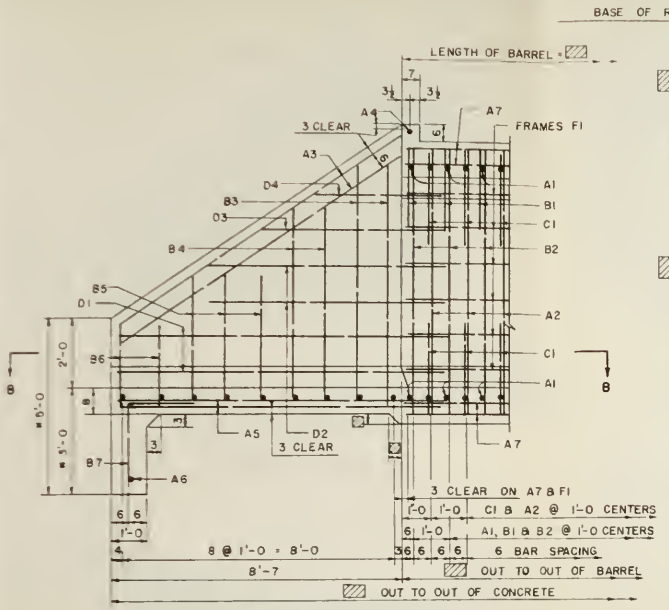
▨ INDICATES ITEMS WHICH VARY WITH DEPTH AND LENGTH OF BOX. SEE FIG. 4, RULING DIMENSIONS, REINFORCEMENT DETAILS AND QUANTITIES FOR THESE ITEMS.

AREA

RECOMMENDED PRACTICE

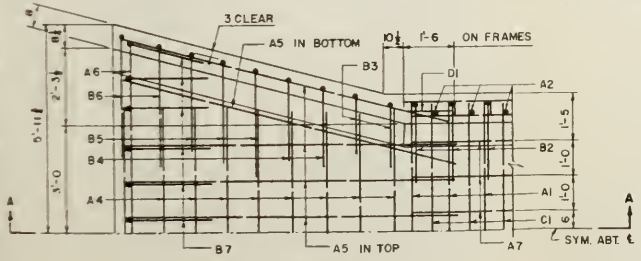
SINGLE 6FT x 6 FT REINFORCED CONCRETE BOX

FIG. 6



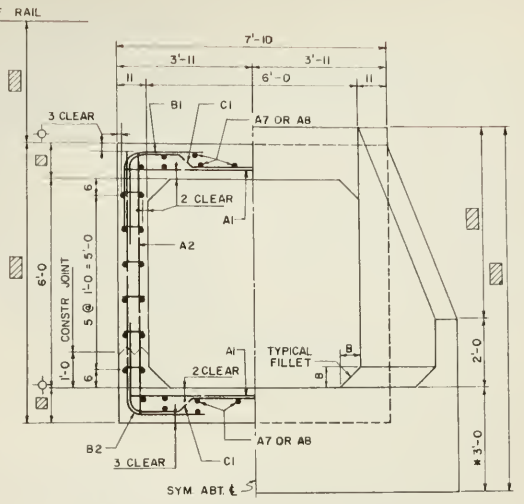
LONGITUDINAL SECTION A-A

* DIMENSION TO BE INCREASED IF FIELD CONDITIONS REQUIRE



SECTION B-B

NOTE
WING WALLS, APRON AND CURB SHALL BE THE SAME ON BOTH ENDS OF THE BARREL

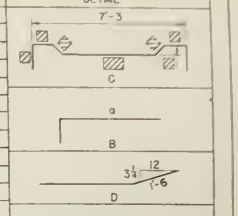


HALF TYPICAL SECTION HALF END VIEW

BILL OF STEEL REINFORCEMENT

MARK	NO REQ	SIZE	LENGTH	LOCATION	a
C1	▨	▨	▨	TOP & BOTTOM SLAB	
B1	▨	▨	▨	TOP CORNERS	
B2	▨	▨	▨	BOTTOM CORNERS	
B3	8	4	7'-9	WING WALLS	6'-6
B4	8	4	7'-1	" "	5'-3
B5	12	4	6'-8	" "	3'-4
B6	8	4	5'-9	" "	2'-2
B7	24	4	4'-10	CUT-OFF WALL	2'-5
D1	8	4	10'-1	WING WALLS	
D2	8	4	7'-5	" "	
D3	4	4	5'-9	" "	
D4	4	4	4'-1	" "	
A1	▨	▨	▨	TOP & BOTTOM SLAB	
A2	▨	4	▨	SIDE WALLS	
A3	8	4	10'-2	WING WALLS	
A4	20	4	7'-4	CURB & APRON	
A5	20	4	9'-10	APRON	
A6	2	4	11'-2	"	
A7	▨	4	▨	LONGITUDINAL BARS	
A8	▨	4	▨	" "	
F1	▨	SEE DETAIL		SIDE WALLS	
F2	▨	" "		" "	

DETAIL



USE 6 DIA. PIN FOR ALL BENDS

GENERAL NOTES

ALL CONCRETE AND CONCRETE WORK SHALL CONFORM TO 1955 AREA MANUAL, CHAPTER 8, AND AREA INSTRUCTIONS FOR MIXING AND PLACING CONCRETE, 1952.

ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE SHALL BE NOT LESS THAN 3500 PSI IN 28 DAYS WITH A MAXIMUM WATER-CEMENT RATIO SPECIFIED IN THE AREA MANUAL, TABLE 1, SEC. J, PART I, FOR THE CONDITION OF EXPOSURE TO WHICH IT WILL BE SUBJECTED.

REINFORCEMENT SHALL BE DEFORMED BARS MEETING ASTM A305-53T, INTERMEDIATE GRADE OPEN HEARTH STEEL, ASTM A15-54T.

ALL BARS SHALL BE FABRICATED IN THE SHOP AND CONFORM WITH THE DETAIL DRAWINGS.

REINFORCEMENT SHALL BE WIRED SECURELY IN CORRECT POSITION

ALL LONGITUDINAL BARS AND FRAMES SHALL HAVE A MINIMUM LAP OF 1'-3 WHERE SPLICED.

FORMS SHALL BE FILLETED AT SHARP CORNERS AND EDGES. LUMBER USED ON INSIDE FORMS SHALL BE SURFACED ON FOUR SIDES AND SIZED TO A UNIFORM THICKNESS, AND BE FREE FROM LOOSE KNOTS OR OTHER DEFECTS. AFTER DISMANTLING FORM BOARDS, THEY SHALL BE CLEANED AND OILED.

BOLTS AND RODS SHALL BE USED FOR INTERNAL TIES AND SO ARRANGED THAT, WHEN FORMS ARE REMOVED, ALL METAL WILL BE ONE INCH OR MORE FROM THE SURFACE OF THE CONCRETE.

CONSTRUCTION JOINTS SHALL BE WIRE-BRUSHED BEFORE THE CONCRETE HAS HARDENED, OR HAVE ALL LAITANCE COMPLETELY REMOVED BY PICKS, CHISELS OR OTHER MEANS. DIRT AND OTHER FOREIGN MATERIAL MUST BE THOROUGHLY CLEANED OFF, AND SURFACES DAMPENED, BEFORE ADDITIONAL CONCRETE IS PLACED.

CONCRETE ABOVE AND BELOW CONSTRUCTION JOINTS SHALL BE CAST MONOLITHICALLY, EXCEPT WHERE IT IS NECESSARY TO PLACE VERTICAL BULKHEADS BECAUSE OF LARGE CONCRETE QUANTITIES INVOLVED OR WHERE JOINTS ARE USED.

CONCRETE SHALL BE THOROUGHLY SPADED NEXT TO FORMS.

IF CONSTRUCTION JOINTS ARE USED, THEY SHALL BE LOCATED AS SHOWN.

FILLING MATERIAL SHALL BE PLACED ALTERNATELY AT EACH SIDE OF BOX, AND TAMPED IN LAYERS NOT MORE THAN 12 IN THICK.

℄ TOP SLAB AND FLOOR THICKNESS MAY BE REDUCED BY USING STIRRUPS.

▨ INDICATES ITEMS WHICH VARY WITH DEPTH AND LENGTH OF BOX. SEE FIG. 4, RULING DIMENSIONS, REINFORCEMENT DETAILS AND QUANTITIES FOR THESE ITEMS.

AREA

RECOMMENDED PRACTICE

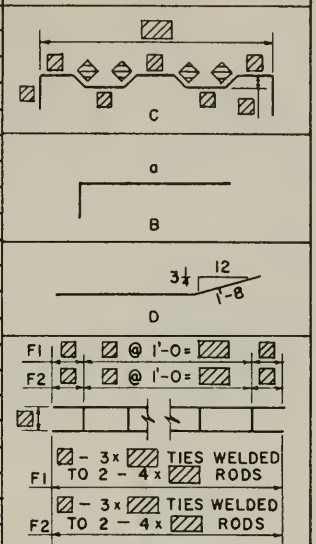
SINGLE 6 FT x 6 FT REINFORCED CONCRETE BOX

FIG 6

BILL OF STEEL REINFORCEMENT

MARK	NO REQ.	SIZE	LENGTH	LOCATION	a
C1	▨	▨	▨	TOP & BOTTOM SLAB	
C2	▨	▨	▨	" " "	
B1	▨	▨	▨	TOP CORNER	
B2	▨	▨	▨	BOTTOM CORNER	
B3	12	4	5'-9	WING WALLS	2'-2
B4	12	4	8'-0	" "	4'-0
B5	12	4	7'-8	" "	5'-10
B6	42	4	5'-0	CUT-OFF WALL	2'-6
D1	8	4	10'-6	WING WALLS	
D2	8	4	7'-9	" "	
D3	8	4	4'-6	" "	
A1	▨	▨	▨	TOP & BOTTOM SLAB	
A2	▨	▨	▨	" " "	
A3	▨	4	▨	SIDE & CENTER WALLS	
A4	▨	4	▨	LONGITUDINAL BARS	
A5	20	4	18'-0	BARREL CURB & APRON	
A6	42	4	10'-2	WING WALLS & APRON	
A7	8	4	10'-6	WING WALLS	
A8	2	4	22'-0	CUT-OFF WALL	
A9	▨	4	▨	LONGITUDINAL BARS	
F1	▨	SEE DETAIL		SIDE WALLS	
F2	▨	SEE DETAIL		" "	

DETAIL



USE 6 DIA. PIN FOR ALL BENDS

955 AREA MANUAL,
CONCRETE, 1952.
L BE NOT LESS THAN
ATIO SPECIFIED IN THE AREA MANUAL,
HICH IT WILL BE SUBJECTED.
ASTM A 305 - 53T, INTERMEDIATE

NFORM WITH DETAIL

T POSITION.
IIMUM LAP OF 1'-3 WHERE

GES. LUMBER USED ON
) TO A UNIFORM THICKNESS,
DISMANTLING FORM

ID SO ARRANGED THAT,
R MORE FROM THE

E THE CONCRETE HAS
ICKS, CHISELS OR OTHER
HLY CLEANED OFF, AND

LL BE CAST
ERTICAL BULKHEADS
JOINTS ARE USED.
MS.
ATED AS SHOWN.
CH SIDE OF BOX, AND

-⊙- TOP SLAB AND FLOOR THICKNESS MAY BE REDUCED BY USING STIRRUPS

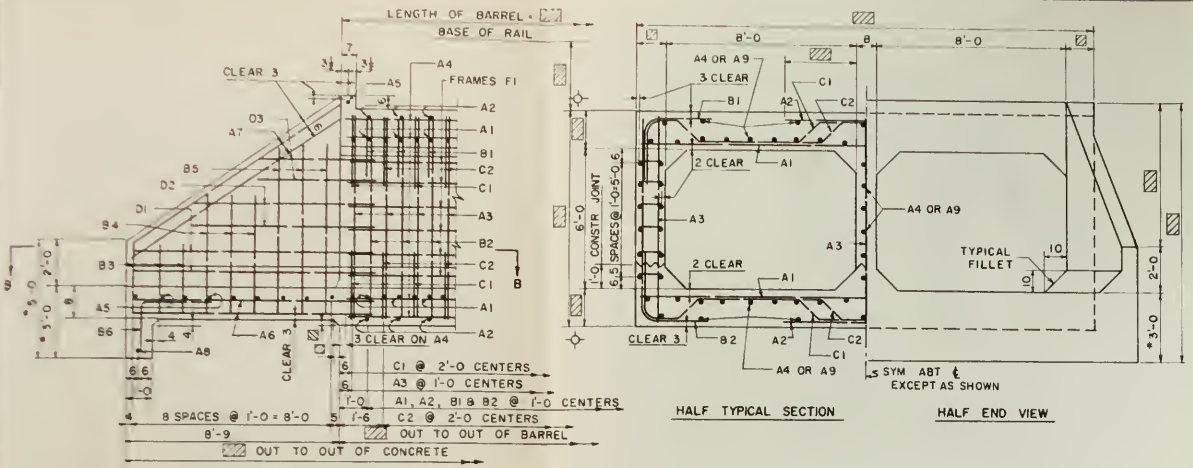
▨ INDICATES ITEMS WHICH VARY WITH DEPTH AND LENGTH OF BOX. SEE FIG. 5, RULING DIMENSIONS, REINFORCEMENT DETAILS AND QUANTITIES FOR THESE ITEMS.

AREA

RECOMMENDED PRACTICE

DOUBLE 8 FT x 6 FT REINFORCED CONCRETE BOX

FIG. 7

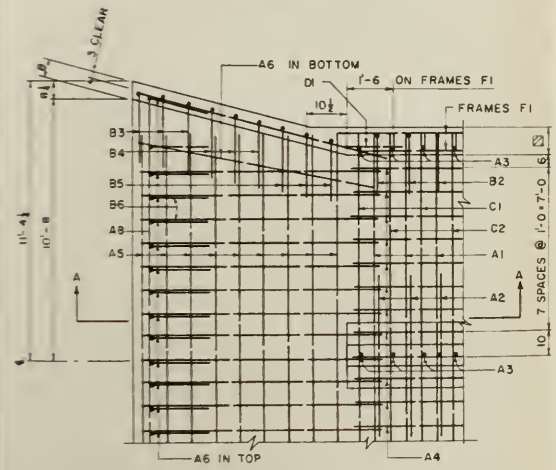


* DIMENSION TO BE INCREASED IF FIELD CONDITIONS REQUIRE.

BILL OF STEEL REINFORCEMENT

MARK	NO REQ	SIZE	LENGTH	LOCATION	a	DETAIL
C1	▨	▨	▨	TOP & BOTTOM SLAB		
C2	▨	▨	▨	" " "		
B1	▨	▨	▨	TOP CORNER		
B2	▨	▨	▨	BOTTOM CORNER		
B3	12	4	5'-9	WING WALLS	2'-2	C
B4	12	4	8'-0	" "	4'-0	
B5	12	4	7'-8	" "	5'-10	a
B6	42	4	5'-0	CUT-OFF WALL	2'-6	B
D1	8	4	10'-6	WING WALLS		
D2	8	4	7'-9	" "		3½ 12 1'-8
D3	8	4	4'-6	" "		D
A1	▨	▨	▨	TOP & BOTTOM SLAB		F1 ▨ @ 1'-0= ▨
A2	▨	▨	▨	" " "		F2 ▨ @ 1'-0= ▨
A3	▨	4	▨	SIDE & CENTER WALLS		▨ - 3 x ▨ TIES WELDED TO 2 - 4 x ▨ RODS
A4	▨	4	▨	LONGITUDINAL BARS		F1
A5	20	4	18'-0	BARREL CURB & APRON		▨ - 3 x ▨ TIES WELDED TO 2 - 4 x ▨ RODS
A6	42	4	10'-2	WING WALLS & APRON		F2
A7	8	4	10'-6	WING WALLS		F
A8	2	4	22'-0	CUT-OFF WALL		
A9	▨	4	▨	LONGITUDINAL BARS		
F1	▨	SEE DETAIL		SIDE WALLS		
F2	▨	SEE DETAIL		" "		

USE 6 DIA. PIN FOR ALL BENDS



NOTE:
WING WALLS, APRON AND CURB SHALL BE THE SAME ON BOTH ENDS OF THE BARREL.

GENERAL NOTES

ALL CONCRETE AND CONCRETE WORK SHALL CONFORM TO 1955 AREA MANUAL, CHAPTER 8, AND AREA INSTRUCTIONS FOR MIXING AND PLACING CONCRETE, 1952.

ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE SHALL BE NOT LESS THAN 3500 PSI IN 28 DAYS WITH A MAXIMUM WATER-CEMENT RATIO SPECIFIED IN THE AREA MANUAL, TABLE I, SEC. 4, PART 1, FOR THE CONDITION OF EXPOSURE TO WHICH IT WILL BE SUBJECTED.

REINFORCEMENT SHALL BE DEFORMED BARS MEETING ASTM A305-53T, INTERMEDIATE GRADE OPEN HEARTH STEEL, ASTM A15-54T.

ALL BARS SHALL BE FABRICATED IN THE SHOP AND CONFORM WITH DETAIL DRAWINGS.

REINFORCEMENT SHALL BE WIRED SECURELY IN CORRECT POSITION.

ALL LONGITUDINAL BARS AND FRAMES SHALL HAVE A MINIMUM LAP OF 1'-3 WHERE SPLICED.

FORMS SHALL BE FILLETED AT SHARP CORNERS AND EDGES. LUMBER USED ON INSIDE FORMS SHALL BE SURFACED ON FOUR SIDES AND SIZED TO A UNIFORM THICKNESS, AND BE FREE FROM LOOSE KNOTS OR OTHER DEFECTS. AFTER DISMANTLING FORM BOARDS, THEY SHALL BE CLEANED AND OILED.

BOLTS AND RODS SHALL BE USED FOR INTERNAL TIES AND SO ARRANGED THAT, WHEN FORMS ARE REMOVED, ALL METAL WILL BE ONE INCH OR MORE FROM THE SURFACE OF THE CONCRETE.

CONSTRUCTION JOINTS SHALL BE WIRE-BRUSHED BEFORE THE CONCRETE HAS HARDENED, OR HAVE ALL LAITANCE COMPLETELY REMOVED BY PICKS, CHISELS OR OTHER MEANS. DIRT AND OTHER FOREIGN MATERIAL MUST BE THOROUGHLY CLEANED OFF, AND SURFACES DAMPENED, BEFORE ADDITIONAL CONCRETE IS PLACED.

CONCRETE ABOVE AND BELOW CONSTRUCTION JOINTS SHALL BE CAST MONOLITHICALLY, EXCEPT WHERE IT IS NECESSARY TO PLACE VERTICAL BULKHEADS BECAUSE OF LARGE CONCRETE QUANTITIES INVOLVED OR WHERE JOINTS ARE USED.

CONCRETE SHALL BE THOROUGHLY SPADED NEXT TO FORMS.

IF CONSTRUCTION JOINTS ARE USED, THEY SHALL BE LOCATED AS SHOWN

FILLING MATERIAL SHALL BE PLACED ALTERNATELY AT EACH SIDE OF BOX, AND TAMPED IN LAYERS NOT MORE THAN 12 IN THICK.

-○- TOP SLAB AND FLOOR THICKNESS MAY BE REDUCED BY USING STIRRUPS

▨ INDICATES ITEMS WHICH VARY WITH DEPTH AND LENGTH OF BOX. SEE FIG. 5, RULING DIMENSIONS, REINFORCEMENT DETAILS AND QUANTITIES FOR THESE ITEMS.

AREA

RECOMMENDED PRACTICE

DOUBLE 8 FT x 6 FT REINFORCED CONCRETE BOX

FIG 7

Report on Assignment 7

Methods For Improving the Quality of Concrete and Mortars

Collaborating with Committee 6

R. A. Ullery (chairman, subcommittee), M. W. Bruns, W. G. Burres, W. J. Galloway, J. F. Halpin, L. M. Morris.

Your committee presents as information the following bibliography on admixtures for concrete.

The intent of this report is to aid the railroad engineer in understanding the use of admixtures and to provide a ready list of references on the subject. References on admixtures are numerous, and no attempt has been made to present a complete list. Only those most pertinent, in the opinion of the committee, have been included. The bibliography is divided into classifications based on the prime function of the admixture, such as air-entrainment, accelerators, etc. However, as a general understanding of admixtures is essential to a potential user, a general subdivision precedes the main body of the bibliography. It is the committee's recommendation that the references to "Admixtures for Concrete" in the following bibliography be read before investigating any specific admixture use.

BIBLIOGRAPHY ON ADMIXTURES FOR CONCRETE

General

1. *Method of Evaluating Admixtures, by F. R. McMillan and T. C. Powers. ACI Proceedings, Vol. 30, March–April 1934, pp. 325–344; (discussion) Vol. 31, Oct. 1934, pp. 66–71.*

Function of admixtures; justification for use of admixtures; basis of design of mixes; factors common to mixes of equal workability; importance of aggregate gradation; evaluating admixtures from test results; results obtained with different admixtures.

2. *Admixtures for Concrete, American Concrete Institute, ACI Proceedings, Vol. 41, No. 2, Nov. 1944, pp. 73–86.*

Admixtures are classified into nine broad groups; factors indicating usefulness of admixtures of each group and effects of use of each group are discussed; groups include accelerators, air-entraining agents, gas forming agents, natural cementing materials, pozzolanic materials, retarders, water-repelling agents, workability agents, and miscellaneous.

3. *Admixtures for Concrete, American Concrete Institute, ACI Proceedings, Vol. 51, Oct. 1954, pp. 113–146.*

An expansion and continuation of Committee 212's Nov. 1944 report. Admixtures are classified into 11 groups: accelerators, retarders, air-training agents, gas-forming agents, cemetitious materials, pozzolans, alkali-aggregate expansion inhibitors, dampproofing and permeability reducing agents, workability agents, grouting agents, and miscellaneous. Classification is according to type of material constituting the admixture and to characteristic effects of its use. Discussion includes factors which might indicate usefulness of admixtures and important effects which may ordinarily be expected from ue of materials in each group.

Air-Entraining Agents

1. *Effect of Air-Entrapping Portland Cement on Resistance to Freezing and Thawing of Concrete Containing Inferior Coarse Aggregate, by E. O. Axon, T. F. Willis, and F. V. Reagel. ASTM Proceedings, Vol. 43, 1943, pp. 981–994– (discussion) pp. 995–1000.*

Results of tests; objective was accelerated test procedure which would give relative results with concretes containing different coarse aggregates, comparable to those obtained from pavements in service; test procedure used in methods of evaluating methods of ameliorating effect of coarse aggregates.

2. *Entrained Air—Its Effect on Constituents of Portland Cement Concrete, by H. L. Kennedy. ASTM Proceedings, Vol. 44, 1944, pp. 821–838.*

Investigations covering effect of two types of air entraining agents on various constituents of portland cement concrete; amount of air entrained by aggregate constituent and two methods of measuring air described; photomicrographs are shown for both cement and fine aggregate in presence of air-entraining agents; concrete with and without air-entraining agents.

3. *Field Use of Cement Containing Vinsol Resin, by C. E. Wuerpel. ACI Proceedings, Vol. 42, Sept. 1945, pp. 49–82.*

Results obtained from 22,398 test specimens manufactured in connection with extensive construction are presented, together with discussion of experience with handling concrete containing over 2,000,000 bbl of vinsol resin cement, during this period, in 168 structures; comparisons are drawn between concrete made with plain cement and with cement interground with vinsol resin as they affect compressive and flexural strength, unit weight and mixing, placing and finishing operations.

4. *Entrained Air in Concrete, American Concrete Institute, ACI Proceedings, Vol. 42, June 1946, pp. 601–694 (discussion) Vol. 43, Dec. 1946, pp. 701–702.*

Symposium includes following papers: Entrained Air-Factor in Design of Concrete Mixes, W. A. Cordon; Recent Experiences with Air-Entrained Portland Cement Concrete in Northeastern States, L. E. Andrews; Experiences with Air-Entraining Cement in Central Mixed Concrete, A. Foster, Jr.; Studies of Concrete Containing Entrained Air, S. Walker and D. L. Bloem; Homogensity of Air-Entraining Concrete, H. L. Kennedy; Methods of Entraining Air in Concrete, E. W. Scripture, Jr.; Effect of Air Entrainment on Stone Sand Concrete, A. T. Goldbeck; Method of Direct Measurement of Entrained Air in Concrete, W. H. Klein and S. Walker; Automatic Dispensing Equipment for Air-Entraining Agents, R. R. Kaufman; Mechanical Dispensing Equipment for Air-Entraining Agents, E. M. Brickett; Simple Accurate Method for Determining Entrained Air in Fresh Concrete, S. W. Benham; Effect of Use of Blended Cements and Vinsol Resin-Treated Cements on Durability of Concrete, W. E. Kellermann; Air-Entraining Concrete—Pennsylvania Department of Highways, W. H. Herman; Portland Rosendale Cement Blends Give High Frost Resistance, B. H. Wait.

5. *Proposed Method of Evaluation of Air-Entraining Admixtures for Concrete. ASTM, Bulletin No. 148, Oct. 1947, pp. 29–30.*

Methods covers evaluation of materials proposed for use as air-entraining admixtures in field; evaluation based on arbitrary stipulation permitting highly standardized testing in laboratory; is not designed to simulate actual job conditions.

6. *Effect of Carbon Black and Black Iron Oxide on Air Content and Durability of Concrete, by T. G. Taylor. ACI Proceedings, Vol. 44, April 1948, pp. 613–624; (discussion) Vol. 45, Dec. 1948, p. 624.*

Tests made to determine effect of certain coloring agents; tests indicate that some material reduce capacity of cement to entrain air and thereby reduce resistance to freezing and thawing; recommended procedure for evaluating coloring agents for use in air-entraining concrete given.

7. *Practices, Experiences, and Tests with Air-Entraining Agents in Making Durable Concrete, by R. F. Blanks and W. A. Cordon. ACI Proceedings, Vol. 45, Feb. 1949, pp. 469, 487; (discussion) Vol. 46, Dec. 1949, p. 488.*

Advantages of air entrainment; U. S. Bureau of Reclamation experiences discussed with regard to pumping, transportation and placing, grading of aggregates, and factors affecting amount of air entrainment; air-entraining agents and cements; measurements of entrained air in concrete.

8. *Entrained Air Simplifies Winter Curing, by J. J. Shideler, H. W. Brewer, and W. H. Chamberlin. ACI Proceedings, Vol. 47, Feb. 1951, pp. 449–459.*

Report on tests undertaken to determine winter protection to prevent air-entrained concrete from freezing; results indicate that amount of winter protection, as presently specified by Bureau of Reclamation, can be reduced when air-entrained concrete is used.

9. *Adjustments in Mix Simple in Change from Normal to Air-Entraining Concrete, by E. Brickett. Concrete, Vol. 60, No. 8, Aug. 1952, pp. 34–35.*

Values of air entrainment; changing from a plain concrete mix to an entrained concrete mix; factors governing the amount of air entraining agent needed in a mix.

10. *Void Spacing as a Basis for Producing Air-Entrained Concrete. ACI Proceedings, Vol. 50, May 1954, pp. 741–760.*

Basic studies show that the function of entrained air is to protect the paste and that the effectiveness depends on the distance from void to void in the paste. Freezing and thawing tests show different mixes have nearly equal frost resistance. The amount of air required for a given spacing factor is directly proportional to the paste content and is greater the smaller the specific surface of the air voids.

Retarders

1. *Materials Which Retard the Setting of Portland Cement, by R. C. Carpenter. Engineering Record, Dec. 31, 1904.*

Gives a brief description of tests made for the purpose of determining the regulating power on the cement of gypsum and chloride of calcium.

2. *Effect of Added Materials on Some Properties of Hydrating Portland Cement Clinkers, by E. S. Newman, et al.*

Journal of Research (National Bureau of Standards) Vol. 30, Research Paper No. 1533, April 1943.

Materials added were gypsum, sugar, calcium chloride, T. DA (grinding aid), tannic acid, triethanolamine, calcium acetate and fluosilicic acid; effects were judged by comparing results of tests of specimens of clinker pastes containing materials under investigation with results of similar tests of clinker pastes to which nothing had been added.

3. *False Set in Portland Cement, by R. F. Blanks, and J. L. Gilliland. ACI Proceedings, Vol. 47, Mar. 1951, pp. 517–532.*

A review of the literature on and recent experiences with false set in portland cement with recommendations for overcoming this condition.

Pozzolans

1. *Pozzuolanas (Pozzolanas), anonymous. Rock Products, Vol. 31, No. 20, Aug. 1928, pp. 56–59.*

Definition of pozzolana; pozzolanas and portland cement; types of pozzolanas available; classification and sources; natural and artificial pozzolanas; nature of pozzolanic action; testing activity of pozzolanas.

2. *Effect of Powdered Admixtures on Concrete, by C. P. Vetter, W. Dreyer and F. J. Mills. Electrical West, Vol. 64, No. 6, May 15, 1930, pp. 372–381.*

Part 1 of report of subcommittee on use of concrete in hydraulic structures of N.E.L.A.; forms of diatomaceous earth and volcanic ash, and their effect on workability, chemical reaction, strength and permeability; analysis of United States diotomites; influence of cement content and flow on fineness modulus of fine and coarse aggregate; constitution and hydrolysis of portland cement; effect of large percentages of Fresno pumicite; effects of admixtures on hydrolysis and compressive strength of concrete; economic value of admixtures; water–cement ratio; strength relation for admixtures of from 3 to 5 percent marine diatomaceous earth.

3. *Classification of Admixtures as to Pozzolanic Effect by Means of Compressive Strength of Concrete, by F. R. McMillan and T. C. Powers. ACI Proceedings, Vol. 34, No. 4, Nov.–Dec. 1937, pp. 129–143; (discussion) Mar.–April 1938, p. 144.*

Experimental study of effect of admixtures on compressive strength of constant cement content; effect of precipitator ash and hydraulic lime; age-strength relationships; strength as index to pozzolanic action; comparison of mixes containing admixtures with plain mixtures.

4. *Concrete Performance in Arid Climate, by T. E. Stanton. ACI Proceedings, Vol. 37, Nov. 1940, pp. 141–155.*

Report on performance of test section of concrete pavement and other studies conducted in Imperial Valley, Calif., on performance of portland cement concrete in arid region, where average humidity and rainfall are low and temperatures in summer are high; curing tests; effect of admixtures of volcanic ash (pozzolanic type), diatomaceous earth, hydrated lime, and calcium chloride, as well as of seven-sack mix.

5. *Overcoming Action of Acids and Sulfate Waters, anonymous. Concrete, Vol. 49, No. 3, Mar. 1941, p. 141, (Cement Mill Section).*

Value of pozzolans in reducing or preventing dissolution of lime compounds from set cement mortar or paste; presence of pozzolanic material results in combination with liberated calcium hydroxide to form new lime pozzolana compound that is insoluble in water; action of sulphate solutions.

6. *Fly Ash as a Pozzolan, by R. F. Blanks. ACI Proceedings, Vol. 46, May 1950, pp. 701–707.*

Effects of fly ash being used at Hungry Horse Dam as constituent in concrete, on workability, compressive strength, durability, permeability, heat of hydration, volume change, and counteraction of expansive reaction between aggregates and alkalis in cements.

7. *Symposium on Use of Pozzolanic Materials in Mortars and Concrete. ASTM Special Technical Publication No. 99, Aug. 1950, p. 208.*

Introduction by T. E. Stanton; Pozzolanic Materials and Their Use in Concrete, by R. E. Davis; Pozzolans Used in Mass Concrete, by H. S. Meissner; Experience with Pozzolanic Materials in Kansas, by G. H. Scholer and R. L. Payton; Effect of Calcination on Natural Pozzuolans, by R. C. Mielenz, L. P. White, and O. J. Glantz; Summary of Methods for Determining Pozzolanic Activity, by W. T. Moran and J. L. Gilliland; Strength Volume Change and Sulfate Resistance of Mortars Containing Portland–Pozzolan Cements, by R. E. Davis, W. C. Hanna, and E. H. Brown; Studies of Some Methods of Avoiding Expansion and Pattern Cracking Associated with Alkali-Aggregate Reaction, by W. C. Larch; Studies of Use of Pozzolans for Counteracting Excessive Concrete Expansion Resulting from Reaction Between Aggregates and Alkalies in Cement, by T. E. Stanton.

8. *Fly Ash—Its Effects When Used in Plastic Concrete and Concrete Products, anonymous. Rock Products, Vol. 56, No. 2, Feb. 1953, pp. 186–188.*

Discussion of advantages of use of fly ash in concrete.

Accelerators

1. *Calcium Chloride as an Admixture in Concrete, by Duff A. Abrams. (Lewis Institute), Structural Materials Research Laboratory, Bulletin No. 13, Nov. 1924.*

Results of investigations to determine effects of calcium chloride and other compounds on compressive strength of concrete.

2. *High Early Strength Concrete, by E. E. Bauer. ACI Proceedings, Vol. 25, 1929, pp. 314–328; (discussion) pp. 329–331.*

Factors which effect rate of hardening of concrete; presents certain data bearing on this subject secured during previous year: factors affecting strength, effect of temperature, effect of calcium chloride, effect of moist curing.

3. *Effect of Calcium Chloride as Admixture in Portland Cement Concrete, by R. C. Sloane, W. J. McCaughey, W. D. Foster, and C. Shreve. Ohio State University Studies—Engineering Experiment Station—Bulletin No. 61, 1931, p. 81.*

Investigation of effect of calcium chloride on rate of hydration of constituent minerals of portland cement and portland cement itself; character of hydration products when cement is set up in calcium chloride solution; difference during curing period in change of moisture content between plain concrete and calcium chloride admixed concrete, also difference during curing period in volumetric changes.

4. *Calcium Chloride in Concreting, anonymous. Calcium Chloride Association, Bulletin No. 28, 1945.*

Influence of calcium chloride on portland cement concrete discussed; results as to stiffening, finishing, strength, weather protection, uniform curing, workability, etc., are favorable; various methods of adding calcium chloride to concrete are described and data on practical experience presented; technical abstracts, references, illustrations, and charts give proof of favorable qualities; suggestions for standard specifications are made.

5. *Recommended Practice for Winter Concreting Methods, by R. W. Spencer. ACI Proceedings, Vol. 45, Sept. 1948, pp. 1–18.*

Standard deals with concreting of thin sections and mass concrete; covering heating of materials, anti-freeze compounds, curing temperature, protection and removal of forms; charts give influence of temperatures on strength.

6. *Calcium Chloride in Concrete, by J. J. Shideler. ACI Proceedings, Vol. 20, No. 1, Mar. 1952, pp. 1–18.*

This presents test results on the effects of type of cement, age, temperature, and mix proportions on the strength of concrete containing $CaCl_2$, as well as effect of $CaCl_2$ on the volume change, heat generated, time of set, alkali-aggregate reaction, resistance to abrasion and sulfate attack of concrete.

7. *Calcium Chloride in Concrete, anonymous, Highway Research Board, Bibliography No. 13 (annotated), 1952.*

Acid and Alkali-Resisting Agents

1. *Chemical Resistance of Cements, by R. Gruen. Pit and Quarry, Vol. 16, No. 5, June 5, 1928, pp. 68–70.*

Results of experiments to determine behavior of ordinary cement in admixture with blast-furnace cement, and also resistance of these mixtures to solutions of salts and acids.

2. *Laboratory and Field Tests of Concrete Exposed to Action of Sulfate Waters, by D. G. Miller and P. W. Manson. U. S. Department of Agriculture Technical Bulletin No. 358, June 1933.*

Early studies of concrete alkali problem; method of measuring alkali solution; sulfate action in relation to strength of solution; actions of sodium sulfate and magnesium sulfate compared; effect of shale in aggregate; curing in water vapor; alumina cements; admixtures; water repellents; surface treatments.

3. *Overcoming Action of Acids and Sulfate Waters, anonymous. Concrete, Vol. 49, No. 3, March 1941, p. 141 (Cement Mill Section).*

Value of pozzolans in reducing or preventing dissolution of lime compounds from set cement mortar or paste; presence of pozzolanic material results in combination with liberated calcium hydroxide to form new lime pozzolana compound that is insoluble in water; action of sulfate solutions.

Waterproofers

1. *Soaps as Integral Waterproofers for Concrete, by A. H. White and J. H. Bateman. ACI Proceedings, Vol. 22, 1926, pp. 535–559.*

A review of known studies on use of soaps as integral waterproofers for concrete together with tests performed to check the effectiveness of waterproofing. The effect of the soap on expansion and contraction of mortars and on compressive strength of concrete is discussed.

2. *Integral Waterproofing Compounds for Concrete, by M. B. Lagaard. University of Minnesota Engineering Experimental Station, Bulletin 6, Vol. 30, No. 77, Nov. 28, 1927.*

Three types of waterproofing methods now in general use; integral method now is only treated; scope of investigations; materials, methods of testing and tests; permeability studies were made to determine effectiveness of waterproofing agents in actual service.

3. *Waterproofing Concrete Integrally, by J. A. Meacham. Concrete, Vol. 3, No. 5, Nov. 1928, pp. 19–21.*

Comparative test for well known commercial methods and materials; means ordinarily employed to secure integrally waterproofed concrete classified under four headings; test methods of making test specimens.

4. *Concrete and Concrete Aggregates. Report of ASTM Committees C–9, ASTM Proceedings, Vol. 29, 1929.*

Report of Subcommittee 15 includes brief discussions of Alberoyd, Alkagel, Antihydro, Aquagel, Barnsdall admixture, cal. Calatom, etc.

5. *Tests of Integral and Surface Waterproofings for Concrete, by C. H. Jumper. U. S. Bureau of Standards Journal, Vol. 3, Nos. 6 and 10, Dec. 1931, pp. 1147–1177.*

Fifty commercial integral waterproofing materials were incorporated into 1:3:6 concrete and subjected to water pressure of 20 psi for 1 year and their permeability noted; 50 surface waterproofing materials were applied to 3 by 6 in concrete cylinders and their absorption determined, after immersion in water, at regular intervals.

Workability Agents

1. *Economic Value of Admixtures, by J. C. Pearson and F. H. Hitchcock, ACI Proceedings, Vol. 20, 1924, pp. 312–347.*

Discusses the effect of admixtures on workability of concrete and gives a suggested method of measuring workability. By measuring workability, admixture effect is deter-

mined. Admixtures used include hydrated lime, kaolin, diatomaceous earth, and calcium chloride. Effect on other properties such as strength, yield, plastic shrinkage, loss of weight, etc., also discussed.

2. *Admixtures and Workability of Concrete, by G. M. Williams. ACI Proceedings, Vol. 27, Feb. 1931, pp. 647–653; (discussion) pp. 1133–1164.*

Report of laboratory study on effect of following admixtures: Canada portland cement, Vankelad A, Vankelad B, Barnsdall admixture, hydrated lime, celite; relative volumes of pastes of same flowability produced with equal weight of admixtures; relative volume increase produced in identical cement-sand mortars to which equal weights of admixtures were added.

3. *Factors of Workability of Portland Cement Concrete, by W. H. Herschel and E. A. Pisapia. ACI Proceedings, Vol. 32, May–June 1936, pp. 641–658.*

Review of test methods designed to measure workability of concrete, harshness, segregation, shear resistance, and stickiness; application of tests to concrete made from various cementitous materials.

4. *The Effect of Addition of Finely Ground Inert Material to Concrete, by R. Chapman and P. E. Olsen. Institute Engineering Aust.—Journal, Vol. 11, No. 8, 1939, pp. 263–278.*

Account of investigations to determine under what conditions the addition of fine inert material (including felspar, quartzite, limestone, and clay) to a mortar or concrete might be of advantage.

5. *What We Have Learned About Air-Entrained Concrete, by J. F. Barbee. ACI Proceedings, Vol. 45, April 1949, pp. 601–612.*

Review of methods of control and effect of air entrainment on workability.

Report of Committee 28—Clearances

A. M. Weston, *Chairman*

E. R. Word,
Vice Chairman,

C. O. Bird
E. S. Birkenwald
B. Bristow
W. S. Campbell
A. B. Chapman
S. M. Dahl
W. T. Davis
J. E. Fanning
J. E. Good
R. L. Goss
J. G. Greenlee
A. R. Harris
W. F. Hart
J. D. Hudson
C. F. Intlekofer
J. D. Jardine
M. L. Johnson
W. P. Kobai
J. E. Krome
J. W. Lyddon
J. W. McMillen
E. E. Mills
A. G. Neighbour
R. C. Nissen
C. E. Peterson
W. F. Pohl
A. D. Quackenbush
A. J. Rankin
W. S. Ray
J. C. Scholtz
J. F. Smith
J. E. South
O. W. Stephens
R. H. Taylor
J. W. Wallenius
H. G. Whittet, Jr.
M. A. Wohlschlaeger

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects.

1. Revision of Manual.

   No report.

2. Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, and with Mechanical and Operating-Transportation Divisions, AAR.

   No report.

3. Clearance diagrams for recommended practice, collaborating with AREA committees concerned, and Electrical Section, AAR.

   No report.

4. Compilation of the railroad clearance diagrams of the various states.

   Progress report, bringing up to date the tabulation of the clearance requirements of the various states ..... page 548

5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating with the Mechanical Division, AAR.

   Progress report, presented as information ..... page 548

6. Study of track centers in relation to current clearance problems, such as permissible size of cars and locomotives in interchange service, collaborating with Committee 5 and the Joint Committee on Clearances, AAR.

   Progress in study, but no report.

The Committee on Clearances,
A. M. Weston, *Chairman.*

AREA Bulletin 526, December 1955.

Report on Assignment 4

Compilation of the Railroad Clearance Requirements of the Various States

E. R. Word (chiarman, subcommittee), W. S. Campbell, S. M. Dahl, R. L. Goss, J. D. Hudson, R. C. Nissen, A. J. Rankin, J. C. Scholtz, O. W. Stephens, R. H. Taylor, A. M. Weston.

Your committee submits as information a tabulation of the clearance requirements of the various States brought up to date as of December 2, 1955.

F.
S.

a
ny
It
ide
ent

is
the
55,

ted
ted

gle
eg,
the

ver
ted
re-
the
ed.
The
be
in.

LEGAL REQUIREMENTS—CLEARANCES

| STATE | ADOPTED CLEARANCE RULES OR REGULATIONS | | MILES OF TRACK AS OF DECEMBER 31, 1942 | PERCENT OF TOTAL MILEAGE IN U.S. | CLEARANCES BASED ON MAXIMUM CAR SIZES | | SPACING BETWEEN TRACKS | | | | | | | | | | | | | | | OVERHEAD CLEARANCES | | | | | | | | | | BUILDINGS STRUCTURES ETC | | | SIDE CLEARANCES | | | | | | | | | | | | | | |

Report on Assignment 5

Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection

Collaborating with the Mechanical Division, AAR

S. M. Dahl (chairman, subcommittee), C. O. Bird, R. L. Goss, A. R. Harris, C. F. Intlekofer, M. L. Johnson, J. E. Krome, R. C. Nissen, A. D. Quackenbush, W. S. Ray, A. M. Weston, M. A. Wohlschlaeger, E. R. Word.

In the last report on this assignment (Proceedings, Vol. 56, 1955, page 559), a method was suggested for calculating the lateral displacement of a moving car at any height above the top of rail on curves with known characteristics and at any speed. It was stated that an allowance must be added to the calculated displacement to provide for the effect of track irregularities and the dynamic behavior of equipment. This present report is concerned with the determination of this allowance.

To avoid repetition and to provide a background for this discussion, the reader is referred to the report entitled "Passenger Ride Comfort on Curved Track" and to the report of Committee 28, both of which will be found in the Proceedings, Vol. 56, 1955, pages 125 and 559, respectively.

The only field data available on this subject are the records of the tests conducted by the Association of American Railroads and reported on in the references mentioned above. This report is, therefore, based on a study of these records.

Fig. 1 shows a typical section of a running test tracing which recorded the angle of the car with the vertical. The average inclination of the car on the curve was 2.6 deg, the minimum, 1.8 deg, and the maximum, 3.3 deg. The maximum variation from the average was, therefore, $2.6 - 1.8 = 0.8$ deg.

Fig. 2 shows the results of an analysis of a tracing taken on a running test over approximately 700 miles of track. The tracing was divided into segments where the speed was uniform, and the maximum variation in roll angle was noted as outlined in the preceding paragraph. The readings were taken on both curved and tangent track, as the variation is substantially the same on both and permitted more points to be platted. It will be noted that some points fall above the line of normal maximum variation. The conditions that caused these high angle values are not known but are assumed to be abnormal or special conditions which would not generally be found or left to remain.

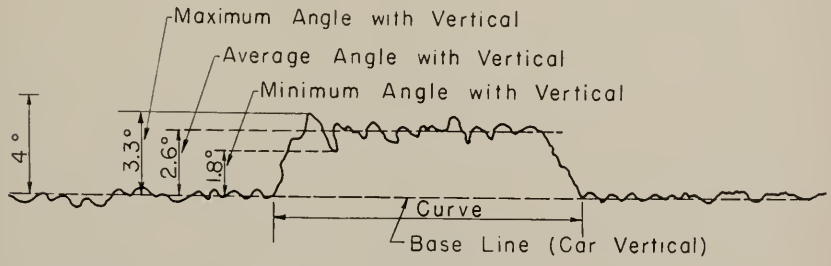


Fig 1 Typical Inclination Record - Running Test.

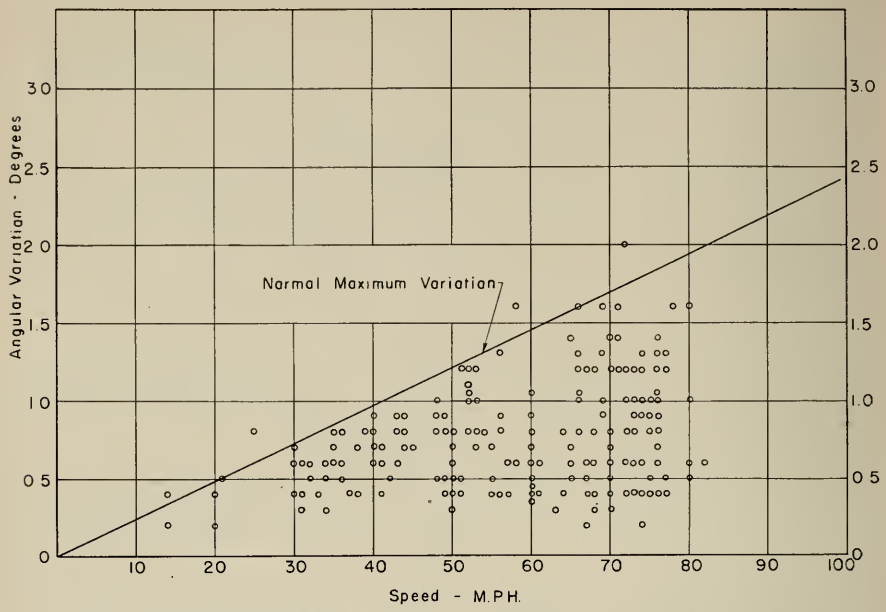


Fig. 2 - Variation in Roll Angle Due To Track and Equipment Irregularities

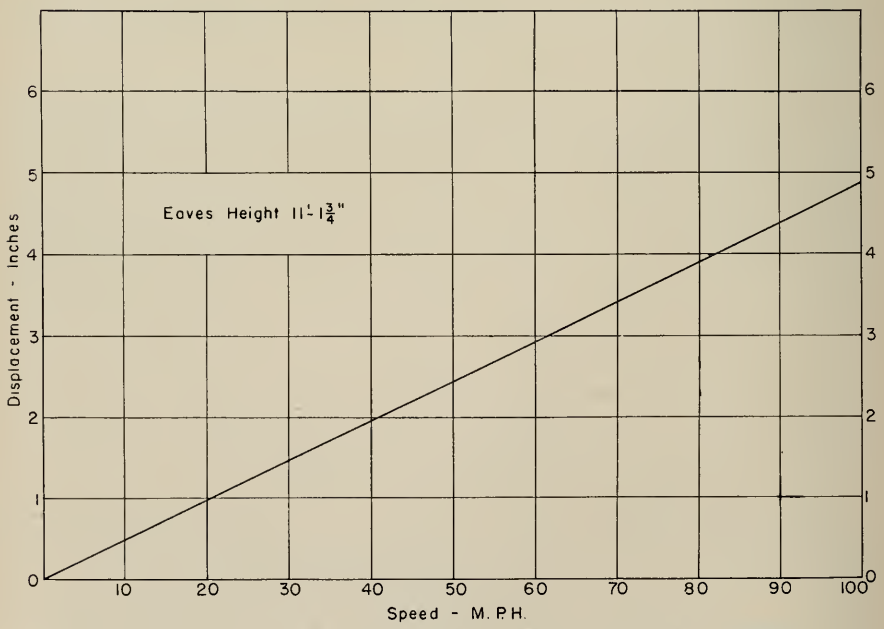


Fig 3 - Displacement Allowance at Eaves Due To Track And Equipment Irregularities

Fig. 3 gives the amount of lateral displacement in inches corresponding to the normal maximum variation line in Fig. 2, at a height of 11 ft 1¾ in above the top of rail. This displacement is an allowance for track and equipment irregularities and is to be added to the calculated displacement of a car based on the unbalanced elevation when moving around a curve.

Further studies will be made to see if a correlation can be made between the amount of roll angle variation and the roll angle determined in a static lean test. This subject is, therefore, being continued.

This report is submitted as information.

Report of Committee 15—Iron and Steel Structures

A. R. Harris, *Chairman*
D. V. Messman,
Vice Chairman,
P. E. Adams
Raymond Archibald
R. C. Baker
H. A. Balke
Ethan Ball
J. L. Beckel
J. E. Bernhardt
E. S. Birkenwald
R. T. Blewitt
M. Block
H. F. Bober
R. N. Brodie
E. E. Burch
V. R. Cooledge
E. F. Croxson
R. P. Davis
W. E. Dowling
C. E. Ekberg
R. W. Gustafson
Shortridge Hardesty
J. M. Hayes
S. C. Hollister
M. L. Johnson
B. G. Johnston
R. L. Kennedy
J. C. King
R. E. Kolm
M. B. Lagaard
Shu-t'ien L.
F. H. Lovell
J. F. Marsh
F. M. Masters
C. T. Morris (E)
James Michalos
B. J. Minetti
N. W. Morgan
Cornelius Neufeld
N. M. Newmark
J. C. Nichols
R. E. Peck
A. G. Rankin
W. S. Ray
C. A. Roberts
G. E. Robinson
C. H. Sandberg
T. C. Shedd
L. L. Shirey
C. E. Sloan
H. F. Smith
J. E. South
G. L. Staley
H. C. Tammen (E)
E. K. Timby
J. P. Walton
C. Earl Webb
H. T. Welty (E)
A. J. Wilson
A. R. Wilson (E)
W. M. Wilson (E)
L. T. Wyly

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revisions of Specifications for Steel Railway Bridges, submitted for adoption and publication in the Manual ..... page 554

   Revision of Specifications for Movable Railway Bridges, submitted for adoption and publication in the Manual ..... page 555

   Revision of Specifications covering Erection of Steel Railway Bridges, submitted for adoption and publication in the Manual ..... page 555

2. Fatigue in high-strength steels; its effect on the current Specifications for Steel Railway Bridges.

   No report.

4. Stress distribution in bridge frames:

   (a) Floorbeam hangers;

   (b) Model railway truss bridge.

   Progress report presented as information ..... page 556

5. Design of steel bridge details.

   No report.

6. Preparation and painting of steel surfaces.
Progress report, presented as information ..... page 556

8. Specifications for design of corrugated metal culverts, including corrugated metal arches.
No report.

10. Substitutes for paint for preservation of steel bridge structures.
Final report, presented as information ..... page 557

11. Economics of various design loadings.
Final report, presented as information ..... page 558

THE COMMITTEE ON IRON AND STEEL STRUCTURES,
A. R. HARRIS, *Chairman.*

AREA Bulletn 527, January 1956.

Report on Assignment 1

Revision of Manual

E. S. Birkenwald (chairman, subcommittee), J. L. Beckel, R. P. Davis, A. R. Harris, J. F. Marsh, Cornelius Neufeld, C. H. Sandberg, G. L. Staley.

Pages 15–1–1 to 15–1–43, incl.

SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

Page 15–1–3, Art. 3 (a) Sec. A.

Add the following sentence to the second paragraph:

Shop drawings may be made in pencil on tracing cloth or vellum, provided that they are photographically reproduced on tracing cloth after completion of the fabrication and/or the erection of the steel.

Revise the fifth paragraph to read:

Legible tracings of the drawings, in good condition, shall be delivered to and become the property of the company upon completion of the contract.

Page 15–1–5, Art. 11, Sec. A.

Amend the last sentence by adding: or as specified by the engineer.

Page 15–1–5, Art. 15, Sec. A.

Revise the name of the article to read: 15. Open Deck.

Change the word "cross" in the first line to "bridge".

Page 15–1–10, Art. 29, Sec. A.

In the second paragraph, fourth line, change the word "number" to "member".

Page 15–1–16, Art. 49, Sec. A.

Change the expression $1\frac{1}{2} + 4t$ to read $1\frac{1}{2} + 4t$, nor 6 in.

Page 15–1–18, Art. 61, Sec. A.

Revise the third paragraph to read:

Cover plates shall be equal in thickness, or shall diminish outwardly in thickness. No plate shall be thicker than the flange angles of a girder or the nominal thickness of the flange of a rolled beam. When cover plates are used, at least one plate of each

flange shall extend the full length of the girder or beam. Other flange plates shall extend far enough to develop the capacity of the plate beyond the theoretical end. The gross area of cover plates in each flange shall not exceed 70 percent of the total flange, consisting of cover plates, flange angles directly connected to cover plates, and side plates, if any, for a plate girder; and cover plates and the beam flange for a rolled beam.

Page 15–1–20, Art. 67, Sec. A.

Add the following second paragraph:

Stiffeners on one side of a plate girder may be used, provided they have the same stiffness as the minimum acceptable pairs of angles. They shall be riveted to the outstanding leg of the compression flange.

Page 15–1–21, Art. 76, Sec. A.

Revise the last sentence by adding the word "system" after the word "floor".

Page 15–1–29, Art. 121, Sec. A.

Revise this article to read:

Steel surfaces shall be prepared and primed in accordance with the recommendations of the Steel Structures Painting Council Manual, Vol. 2. The surface preparation and priming shall be in accordance with the particular system selected from Table I—General Painting Guide for Steel Structures, of the Manual.

Surfaces to be in contact when assembled shall receive, in the shop, one coat of lacquer or other protective coating, suitable for the expected period of exposure before erection.

Pages 15–2–1
to 15–2–73, incl.

SPECIFICATIONS FOR MOVABLE RAILWAY BRIDGES

Page 15–2–19, Art. 17, Sec. C.

In the second paragraph, first item, change the word "less" to the word "more".

Page 15–2–19, Art. 18, Sec. C.

In the second paragraph, second line, change the word "net" to the word "nut".

Pages 15–5–1
to 15–5–6, incl.

SPECIFICATIONS FOR THE ERECTION OF STEEL RAILWAY BRIDGES

Page 15–5–5, Art. 18.

Revise the name of the article to read: 18. Field Painting.

Revise the article to read:

The intermediate and finish coats of paint shall be in accordance with the recommendations of the Steel Structures Painting Council Manual, Vol. 2, for the particular system selected from Table I—General Painting Guide for Steel Structures, of the Manual.

The field painting of the top flanges of stringers and deck girders shall be done before the decks are placed.

Report on Assignment 4

Stress Distribution in Bridge Frames

(a) Floorbeam hangers
(c) Model railway truss bridge

C. H. Sandberg (chairman, subcommittee), J. E. Bernhardt, E. S. Birkenwald, J. F. Marsh, F. M. Masters, N. M. Newmark, G. L. Staley, C. Earl Webb, L. T. Wyly, J. Michalos, E. K. Timby, N. W. Morgan, E. F. Ball, J. M. Hayes.

Your committee submits the following report of progress.

The research project on the study and investigation of the causes and remedies of failures in floorbeam hangers in railway truss bridges and counterweight trusses of bascule bridges has been conducted at Purdue University under the direction of Prof. L. T. Wyly, then research professor of structural engineering and head of department. The three final reports are now ready for publishing and consist of the following: Static and Dynamic Tests of the Missouri–Kansas–Texas Railway Bridge at Erie, Kans.; Static Tests on the Missouri–Kansas–Texas Bridge at Dennison, Tex.; and Static Tests on the Texas & New Orleans Railway Bridge at Wax Lake, La. These reports all cover measurements of live-load stresses in floorbeam hangers. The field work was done in part by the AAR research staff and in part by Purdue University.

Work is now in progress on recommendations for changes in the specifications covering the design of floorbeam hangers.

After many troubles and delays, final arrangements have been made and contracts signed for conducting the 100-ft truss bridge research project at Northwestern Technological Institute. It is planned that by the middle of 1956 the truss bridge will be erected and the tests begun.

Report on Assignment 6

Preparation and Painting of Steel Surfaces

R. C. Baker (chairman, subcommittee), A. R. Harris, R. N. Brodie, J. C. King, F. M. Masters, N. W. Morgan, R. E. Peck, A. G Rankin, W. S. Ray, C. A. Roberts, L. L. Shirey, C. E. Sloan, C. Earl Webb.

This is a progress report, submitted as information.

The recommended Manual revisions, page 15–1–29, Art. 121, Sec. A, and page 15–5–5, Art. 18 (see report on Assignment 1—Revision of Manual), applying to shop and field painting of bridges, make it certain that the specifications for cleaning and painting steel are in accordance with the best known practices. The particular system of surface preparation and priming, and the type of paint, can be specified in the same easy, precise method as the steel itself—by reference to a specification number.

The Missouri Pacific brine drippings paint test near Chester, Ill., where the paints have been exposed for 24 months, indicates that the synthetic resin paints, such as alkyds, phenolics, chlorinated rubbers, and vinyls, are performing excellently on the blast and steam-cleaned surfaces. On those surfaces which were hand and steam cleaned, there is evidence of initial failure in these paints.

The committee is cooperating with the Steel Structures Painting Council on the following new tests:

The Seaboard Air Line Brine Drippings Paint Test. The purpose of this test is to evaluate the performance of chemically resistant synthetic resin paints on the floor system of steel railroad bridges exposed to brine drippings—but without benefit of blast cleaning, or steam cleaning—in maintenance painting. Two bridges of the Seaboard Air Line are to be used in this test. The primary test will include seven floorbeams of the through truss draw bridge across the Ashley River in Charleston, S. C. The second bridge in the test is the Seaboard bridge across the Santee River at Jamestown, S. C., where, because of the high speed of the trains, brine drippings are thrown almost clear of the floor system, but much lands on the top surfaces of the bottom chord of the truss. The various groups of paints to be tested will be: (1) vinyl solution, (2) vinyl mastic, (3) chlorinated rubber, (4) neoprene, (5) epoxy, amine cured, (6) phenolic, (7) alkyd, and (8) asphalt mastic.

The Pennsylvania Railroad River Branch Bridge Paint Test. The purpose of this test is to evaluate the relative performance of paint on steel structures that are cleaned and primed in the shop, in contrast to those that are shipped unpainted, weathered to remove mill scale by rusting, hand or power-tool cleaned, and then painted. The test will be run in cooperation with the Pennsylvania Railroad on its River Branch U. G. Bridge No. 30.88 across Short Creek, 0.08 mile east of Rayland, Ohio. The bridge will consist of two 75-ft 6-in deck plate-girder spans with reinforced concrete ballast deck. The east span will be cleaned and painted in the shop with primer coat. After erection, the 2 coats of protective paint will be applied. The west span will not be cleaned or painted in the shop. It will be erected and allowed to weather about 9 months. It will then be cleaned and painted with 1 coat of primer and 2 coats of protective paint.

Report on Assignment 10

Substitutes for Paints for Preservation of Steel Bridge Structures

C. E. Ekberg (chairman, subcommittee), H. A. Balke, E. E. Burch, W. E. Dowling, N. W. Morgan, L. L. Shirey, H. F. Smith.

Subsequent to the assignment of this subject, the Steel Structures Painting Council Manual has been published, which includes specifications for the substitutes originally contemplated (heavy road oils and asphalt compounds). Furthermore, it is a matter of opinion whether or not there are any satisfactory substitutes for paint systems that have proven their merit.

Accordingly, this assignment has been discontinued.

Report on Assignment 11

Economics of Various Design Loadings

E. E. Burch (chairman, subcommittee), R. C. Baker, E. F. Croxson, C. E. Ekberg, B. J. Minetti, C. A. Roberts, G. E. Robinson, L. L. Shirey, H. F. Smith, J. E. South, E. K. Timby.

The complete dieselization of some Class I railroads has caused their managements to request a reduction in design loading of bridges from the present E 72 to E 60 or E 50.

It is true that the ratings of present diesels are in the E 35 to E 56 range, but loads are now being hauled rating as high as E 82. Wrecker cranes, snowplows, piledrivers and other railroad equipment rate up to E 65. There are still some steam locomotives in service which produce ratings in the range of E 72. The history of steam locomotives shows a steady increase of weight on drivers, and we can be sure that the trend of design in diesel locomotives will follow the same pattern, since tractive forces depend on driver weights.

The supporting data shown in the accompanying tables indicate that the decrease in overall cost of a bridge to be realized by reducing its rating from E 72 to E 50 is less than 3 percent. This decrease is due to a lesser weight of steel in the main structural members and applies only to the mill price, since the costs for bracing, fabrication, erection, engineering, etc., remain practically constant for the three design loadings.

(Text continued on page 564)

COMPARATIVE COSTS FOR ONE 140′ 0″ THROUGH GIRDER SPAN ON SECOND-HAND STEEL PILE PIERS WITH REINFORCED CONCRETE CAPS—OPEN TIMBER FLOOR —TANGENT TRACK

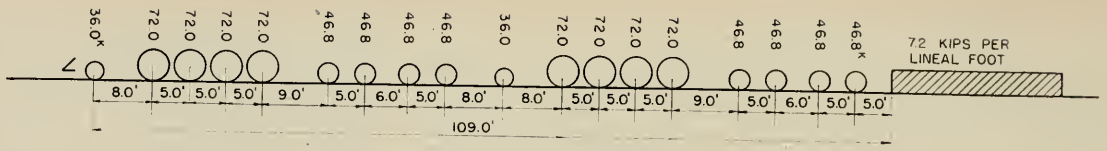
	Unit	E 72		E 60		E 50	
		Material	$	Material	$	Material	$
Falsework			$ 8,545		$ 8,545		$ 8,545
Substructure							
Excavation	cu yd	200	800	200	800	195	780
Steel piles	lb	173,728	8,686	173,728	8,686	157,490	7,875
Steel caps and bracing	lb	7,357	368	7,357	368	6,981	349
Concrete	cu yd	138	8,280	138	8,280	138	8,280
Reinforcing steel	lb	9,800	1,176	9,800	1,176	9,800	1,176
Drive piles and frame caps			3,622		3,622		3,289
Superstructure							
Structural steel base plus extras—variable	lb	410,000	19,024	387,100	17,961	375,300	17,414
Structural steel miscellaneous—variable	lb	410,000	3,526	387,100	3,329	375,300	3,228
Structural steel—constant			35,515		35,515		35,515
Erection			5,254		5,233		5,201
Drawings			1,501		1,501		1,501
Engineering			1,880		1,880		1,880
TOTAL COSTS			$98,177		$96,896		$95,033
Total cost, decrease from E 72, percent					1.3		3.2
Total cost, decrease from E 60, percent							1.926
Substructure decrease from E 72 percent					0.0		4.09
Substructure decrease from E 60 percent							4.09
Superstructure decrease from E 72 percent					1.85		2.83
Superstructure decrease from E 60 percent							1.00

COMPARATIVE COSTS FOR REPLACEMENT OF AN OLD 123′ THOUGH TRUSS WITH A NEW TRUSS OF HEAVIER DESIGN, ALTERING AND REUSING THE PRESENT PIERS OPEN TIMBER FLOOR—TANGENT TRACK

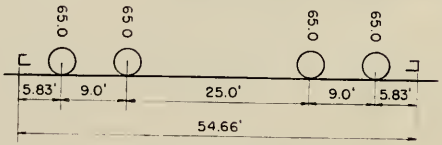
Unit	E 72		E 60		E 50	
	Material	$	Material	$	Material	$
Falsework		$11,452		$11,452		$11,452
Substructure						
Concrete cu yd	102	5,202	102	5,202	102	5,202
Reinforcing steel lb	1,096	165	1,096	165	1,096	165
Superstructure						
Structural steel base plus extras—variable lb	183,200	8,464	155,500	7,184	151,020	6,977
Structural steel miscellaneous—variable lb	183,200	1,429	155,500	1,213	151,020	1,178
Structural steel—constant		23,044		23,044		23,044
Structural steel drawings		2,916		2,916		2,916
Floor		3,601		3,601		3,601
Steel erection		6,338		6,241		6,229
Dismantle old steel		478		478		478
Engineering		1,339		1,339		1,339
Total Costs		$64,428		$62,835		$62,581
Total cost, decrease from E 72 percent				2.480		2.870
Total cost, decrease from E 60 percent						0.404

COMPARATIVE COSTS FOR A FIVE-BEAM STEEL PLATE BALLAST DECK STRUCTURE WITH REINFORCED CONCRETE PIERS AND ABUTMENTS ON WOOD PILES—TANGENT TRACK. ONE 35′ 3″ SPAN, TWO 44′ 1″ SPANS, AND ONE 33′ 3″ SPANS

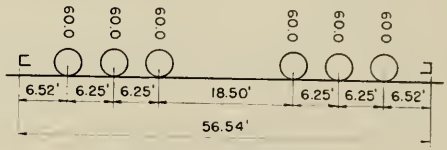
Unit	E 72		E 60		E 50	
	Material	$	Material	$	Material	$
Falsework		$ 17,192		$ 17,192		$ 17,192
Substructure						
Excavation cu yd	570	2,936	570	2,936	564	2,905
Creosoted piling lin ft.	7,710	17,349	7,260	16,335	7,260	16,335
Concrete cu yd	610	35,075	610	35,075	600	34,500
Reinforcing steel lb	40,000	5,400	40,000	5,400	40,000	5,400
Superstructure						
Structural steel base plus extras—variable lb	174,100	7,887	164,850	7,468	160,730	7,281
Structural steel miscellaneous—variable	174,100	2,995	164,850	2,835	160,730	2,765
Structural steel—constant		28,622		28,622		28,622
Erection		9,033		9,008		8,981
Fascia girder concrete cu yd	115	7,188	115	7,188	115	7,188
Fascia girder reinforcing steel lb	16,080	2,050	16,080	2,050	16,080	2,050
Deck Waterproofing		2,938		2,938		2,938
Handrail		2,308		2,308		2,308
Ballast		481		481		481
Ties		453		453		453
Drawings		2,659		2,659		2,659
Engineering		4,614		4,614		4,614
Total costs		$149,180		$147,562		$146,672
Total cost, decrease from E 72 percent				1.094		1.684
Total cost, decrease from E 60 percent						0.605
Substructure decrease from E 72 percent				1.392		2.242
Substructure decrease from E 60 percent						0.843
Superstructure decrease from E 72 percent				0.742		1.176
Superstructure decrease from E 60 percent						0.386



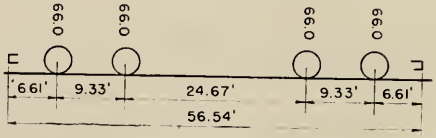
COOPER E 72 LOADING



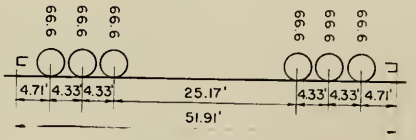
ROAD PASSENGER DIESEL
(TOTAL WT. = 260.0 KIPS)



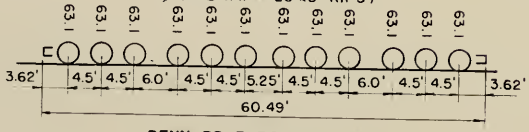
ROAD SWITCHER DIESEL
(TOTAL WT. = 360.0 KIPS)



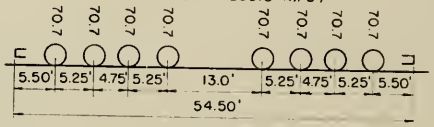
ROAD FREIGHT DIESEL
(TOTAL WT. = 264.0 KIPS)



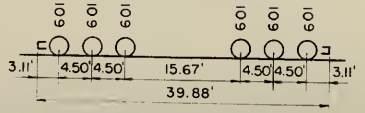
TRANSFORMER CAR
(TOTAL WT. = 399.6 KIPS)



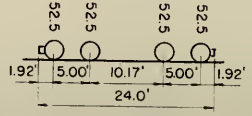
PENN. RR. F-38 FLAT CAR
(TOTAL WT. = 757.0 KIPS)



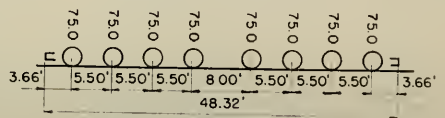
8-AXLE HOT METAL CAR
(TOTAL WT. = 565.6 KIPS)



6-AXLE HOT METAL CAR
(TOTAL WT. = 654.0 KIPS)



U22 ORE CAR
(TOTAL WT. = 210.0 KIPS)



PENN. RR. PROPOSED FLAT CAR
(TOTAL WT. = 600.0 KIPS)

FIG. 1 AXLE WEIGHTS AND SPACINGS

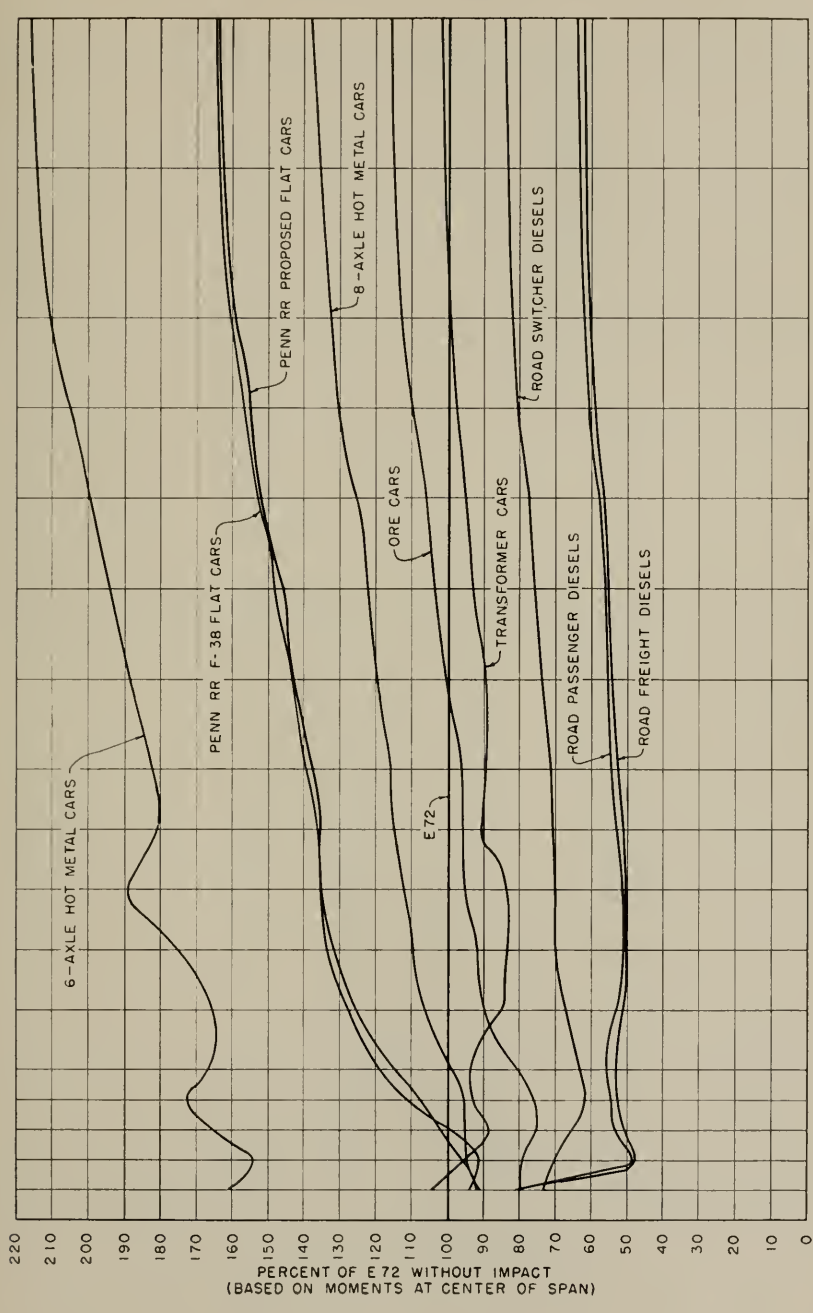
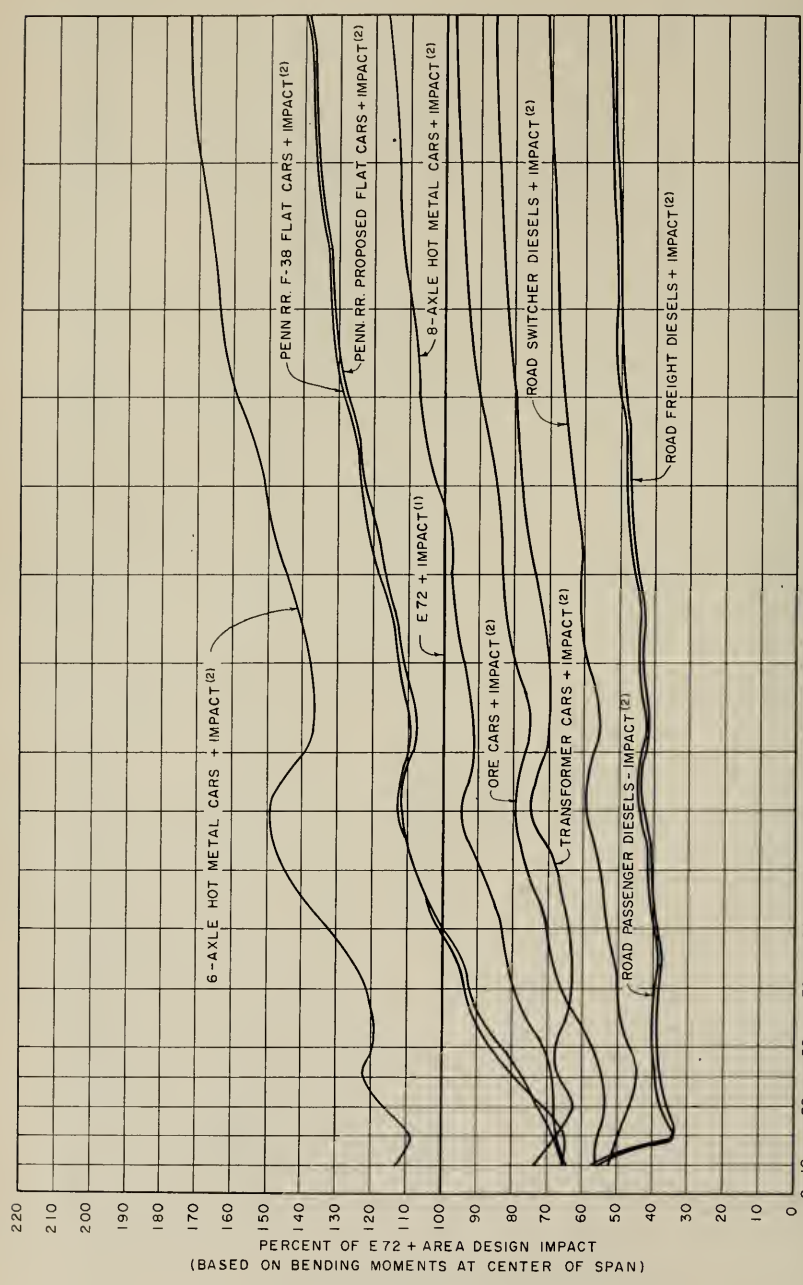

6-AXLE HOT METAL CARS
PENN RR F-38 FLAT CARS
PENN RR PROPOSED FLAT CARS
8-AXLE HOT METAL CARS
ORE CARS
E 72
TRANSFORMER CARS
ROAD SWITCHER DIESELS
ROAD PASSENGER DIESELS
ROAD FREIGHT DIESELS
PERCENT OF E 72 WITHOUT IMPACT
(BASED ON MOMENTS AT CENTER OF SPAN)
SPAN LENGTH IN FEET
0 10 30 50 70 90 110 130 150 180 210 240 270 300 350 400
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220

FIG. 2 – COMPARISON OF MAXIMUM BENDING MOMENTS–STATIC LOADING


6-AXLE HOT METAL CARS + IMPACT(2)
PENN RR. F-38 FLAT CARS + IMPACT(2)
PENN RR. PROPOSED FLAT CARS + IMPACT(2)
8-AXLE HOT METAL CARS + IMPACT(2)
E 72 + IMPACT(1)
ORE CARS + IMPACT(2)
TRANSFORMER CARS + IMPACT(2)
ROAD SWITCHER DIESELS + IMPACT(2)
ROAD PASSENGER DIESELS - IMPACT(2)
ROAD FREIGHT DIESELS + IMPACT(2)
PERCENT OF E 72 + AREA DESIGN IMPACT
(BASED ON BENDING MOMENTS AT CENTER OF SPAN)
SPAN LENGTH IN FEET
0 10 30 50 70 90 110 130 150 180 210 240 270 300 350 400
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220

(1) AREA DESIGN IMPACT FOR LOCOMOTIVES WITH HAMMER BLOW
(2) AREA RATING RULES IMPACT FOR ROLLING EQUIPMENT WITHOUT HAMMER BLOW AT 10 MPH

FIG. 3-COMPARISON OF MAXIMUM BENDING MOMENTS - SLOW SPEED LOADING

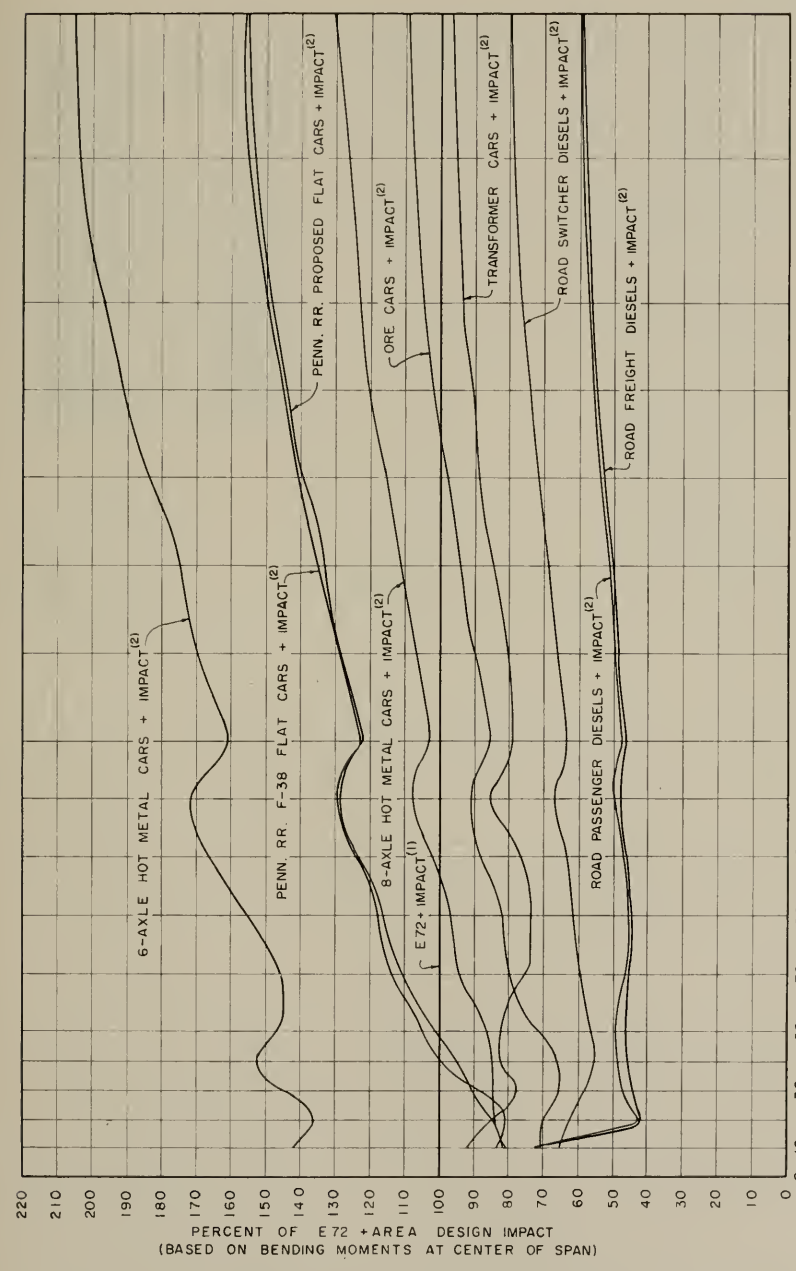

6-AXLE HOT METAL CARS + IMPACT(2)
PENN. RR. F-38 FLAT CARS + IMPACT(2)
PENN. RR. PROPOSED FLAT CARS + IMPACT(2)
8-AXLE HOT METAL CARS + IMPACT(2)
ORE CARS + IMPACT(2)
E72+ IMPACT(1)
TRANSFORMER CARS + IMPACT(2)
ROAD SWITCHER DIESELS + IMPACT(2)
ROAD PASSENGER DIESELS + IMPACT(2)
ROAD FREIGHT DIESELS + IMPACT(2)
PERCENT OF E72 + AREA DESIGN IMPACT
(BASED ON BENDING MOMENTS AT CENTER OF SPAN)
SPAN LENGTH IN FEET
0 10 30 50 70 90 110 130 150 180 210 240 270 300 350 400
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
(1) AREA DESIGN IMPACT FOR LOCOMOTIVES WITH HAMMER BLOW
(2) AREA DESIGN IMPACT FOR ROLLING EQUIPMENT WITHOUT HAMMER BLOW

FIG. 4 – COMPARISON OF MAXIMUM BENDING MOMENTS – HIGH SPEED LOADING

Conclusions

1. The maximum savings that can be realized in dropping from E 72 to E 50 loading is about 3 percent of the total cost of the bridge.

2. The E 50 design cannot be condoned because of car gross weights.

3. The corresponding maximum savings in dropping from E 72 to E 60 loading is about 1½ percent.

4. In view of the prospect that locomotive design may be expected to outmode E 60 loading in the future, the change from E 72 loading cannot be justified.

Report of Committee 7—Wood Bridges and Trestles

W. C. Howe, *Chairman.*
S. L. Goldberg,
Vice Chairman,
W. L. Anderson
H. Austill (E)
J. C. Boston
W. W. Boyer
T. P. Burgess
H. M. Church (E)
F. H. Cramer
R. D. Culbertson
E. M. Cummings
E. R. Dabler
B. E. Daniels
K. L. DeBlois
J. P. Dunnagan
P. R. Eastes
J. T. Evans
W. A. Genereux
S. F. Grear (E)
E. L. Haberle
Nelson Handsaker
F. J. Hanrahan
M. W. Jackson
R. E. Jacobus
Milton Jarrell
C. S. Johnson
C. S. Johnson, Jr.
R. P. A. Johnson
J. V. Johnston
W. D. Keeney
L. P. Keith
J. R. Kelly
J. C. Korte*
H. G. Kriegel
A. L. Leach
C. V. Lund
W. B. Mackenzie
F. W. Madison
L. J. Markwardt
T. K. May
P. L. Montgomery
C. H. Newlin
W. H. O'Brien
W. A. Oliver
O. C. Rabbitt
H. S. Rimmington*
W. C. Schakel
A. H. Schmidt
F. E. Schneider
B. J. Shadrake
Josef Sorkin
R. L. Stevens
F. L. Thompson
L. W. Watson
Clifford Wendell
A. M. Westenhoff
W. C. Wilder
Committee

(E) Member Emeritus.
* Deceased.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress in study, but no report.

2. Grading rules and classificaton of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested

   Progress in study, but no report.

3. Specifications for design of wood bridges and trestles.

   Progress in study, but no report.

4. Methods of fireproofing wood bridges and trestles, including fire-retardant paints, collaborating with Committees 6 and 17 and with the Fire Protection and Insurance Section, AAR.

   Progress report, presented as information ..... page 566

5. Specifications for structural glued laminated lumber, collaborating with Committees 6 and 17.

   No report.

6. Design of timber-concrete composite decks, collaborating with Committee 8.

   Progress report, presented as information ..... page 569

7. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools, and equipment, collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR.

Final report, presented as information ..... page 570

The Committee on Wood Bridges and Trestles,
W. C. Howe, *Chairman.*

AREA Bulletn 527, January 1956.

Report on Assignment 4

Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints

Collaborating with Committees 6 and 17 and with the Fire Protection and Insurance Section AAR

R. E. Jacobus (chairman, subcommittee), J. C. Boston, W. W. Boyer, B. E. Daniels, J. P. Dunnagan, E. L. Haberle, J. V. Johnston, W. D. Keeney, J. R. Kelly, A. L. Leach, F. W. Madison, L. J. Markwardt, T. K. May, W. B. Mackenzie, P. L. Montgomery, H. S. Rimmington, W. C. Schakel, F. E. Schneider, F. L. Thompson.

This is a progress report submitted as information, on an investigation of fire-retardant coatings for use on timber trestles being conducted for your committee at the AAR Research Center by the Engineering Division research staff. The investigation is being carried out by S. K. Coburn, chemical engineer, assisted by K. J. Morris and Jack Oda, laboratory assistants, under the general direction of G. M. Magee, director of engineering research.

Introduction

A comprehensive analysis of the problem dealing with fire-retardant coatings and the burning characteristics of treated timber is outlined in the Proceedings, Vol. 56, 1955, pages 636 to 641, incl.

The need for quantitative information was demonstrated, as will be noted by consideration of the results shown on pages 638 and 639. Specimens of southern yellow pine treated with creosote by one supplier and a 50:50 mixture of creosote and petroleum by another supplier developed widely divergent below-surface temperatures upon being burned under controlled conditions. It is obvious that confusion would arise if a particular fire-retardant coating material proved satisfactory on one specimen and failed on the other. From this work it was recognized that standardization of preservative, wood species, and retention of preservative were necessary if valid relationships were to be established and the true behavior of treated timber under the influence of fire was to be understood.

Toward this end a large quantity of southern yellow pine and Douglas fir of B, or better, quality was purchased and treated under a variety of conditions at the U. S. Forest Products Laboratory, Madison, Wis. The preservatives used were creosote, a 60:40 mixture of creosote and coal tar, and a 50:50 mixture of creosote and petroleum, all of which met AWPA specifications. The freshly treated timber was allowed to age for some 7 months prior to use.

Atmospheric exposure test of coated specimens on roof of AAR Research Center.

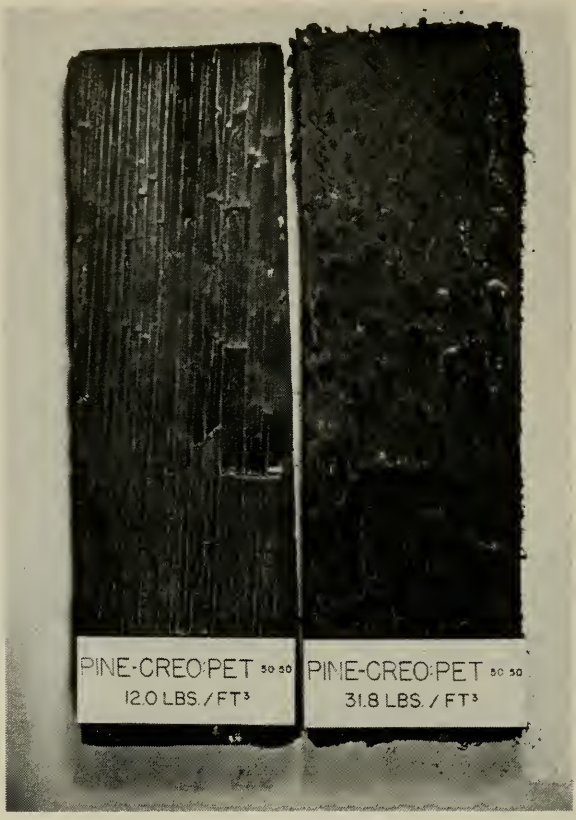
Below-Surface Temperature Studies During Combustion

A method was devised to continuously record automatically the temperature rise within a burning timber specimen at various depths below the surface by means of specially constructed thermocouples attached to an oscillograph. To date some 60 specimens, representing each of the systems being studied, have been burned. Already significant differences have become apparent, and additional work under way will verify statistically the results obtained.

Evaporation Studies

Because the preservatives commonly used to treat timber are composed of mixtures of materials which in themselves are made up of hundreds of compounds, each varying in volatility or evaporation rate, it became necessary to initiate accelerated evaporation studies. Several factors are being considered. One is the change in fire potential upon aging; another is the difference in behavior insofar as adhesion of paint is concerned.

Significant differences in connection with evaporation rates are becoming apparent within preservative groups in which retention is varied from 10 to 30 lb per cu ft. Other



Example of variation and burning characteristics.

differences have been noted in relating the relative volatility of creosote with that of creosote and petroleum, and creosote and coal tar. Preliminary results compare favorably with those reported by Bell Telephone Company investigators.

Extraction Studies

Extraction studies yield valuable information. For example, moisture content can be obtained only by extracting samples of treated timber. No other method yields accurrate yields. Additional information can be obtained by extraction of oil from specimens subjected to accelerated evaporation. By analysis of the extracted oil the potency of the residual oil can be determined. In addition, it is of interest to learn what proportion of the weight loss incurred by burning a wood specimen consists of wood and oil, respectively. This can be accomplished by extraction. These studies were recently initiated and are continuing.

Fire-Retardant Coating Specifications

A start has been made toward the development of tentative specifications for a fire-retardant coating material. Our laboratory experience coupled with that of the field tests

carried out in conjunction with the Santa Fe work have enabled us to define certain factors of importance. Laboratory work leading to the completion of the specification is continuing.

Correlation Studies

An important question in the minds of the subcommittee is the extent to which tests of a coating material applied to relatively small specimens in the laboratory will be indicative of actual service performance on full-size trestle timbers and piling. Accordingly, a correlation study has been started in which a protective coating material, found to give reasonably satisfactory results in the full-scale field tests of the Santa Fe, will be applied to small specimens and put through the laboratory burning and exposure tests to determine the extent of protection afforded in these tests. For this purpose, southern yellow pine and Doug'as fir of B and better quality were treated by the Santa Fe with its standard 50:50 mixture of creosote and petroleum at Albuquerque, N. M., and returned to the Research Center for complete testing, i.e., burning and extraction with and without the aforementioned coating material.

A-Bomb Exposure

Pine piling treated with creosote, creosote and coal tar, and creosote with petroleum were coated with a white pigmented and a black pigmented fire-retardant coating material of identical composition. These coated piling, in addition to uncoated and untreated piling, were exposed on Yucca Flats at the Atomic Energy Commission's proving grounds in the spring of 1955 in Operation CUE. The results of the tests are still being classified; however, it can be indicated that useful information was developed.

Report on Assignment 6

Design of Timber–Concrete Composite Decks

Collaborating with Committee 8

W. A. Oliver (chairman, subcommittee), J. C. Boston, E. M. Cummings, E. R. Dabler, W. A. Genereux, C. S. Johnson, C. S. Johnson, Jr., W. D. Keeney, J. C. Korte, T. K. May, W. H. O'Brien, O. C. Rabbitt, H. S. Rimmington, A. H. Schmidt, B. J. Shadrake, Josef Sorkin.

This is a progress report, submitted as information.

Your committee has in preparation a report on design procedures and specifications for timber-concrete composite decks which it expects to submit next year for consideration for inclusion in the Manual. A year ago it submitted as its report a paper by T. K. May, director of technical service, West Coast Lumbermen's Association, entitled Composite Timber–Concrete Construction. This was published in Bulletin 520, January 1955, page 642, and may be found in the Proceedings, Vol. 56, 1955, same page. It's an excellent coverage of the development and use of this form of construction, and the committee is recommending it again this year to interested persons.

Timber-concrete composite decks are suitable for highway overhead structures, and a considerable footage has already been built by certain railroads, particularly of the type developed primarily by the American Wood Preservers' Institute. This type is characterized by the use of the trapezoidal steel shear developers and uplift spikes.

A partial list of timber-concrete composite decks built by three major railroads includes a total of 3273 ft. These range in span from 11 to 26 ft and are made up of either alternating 2 by 4-in and 2 by 6-in or 2 by 6-in and 2 by 8-in laminations. The earliest of these was built in 1933, and there is one presently under construction. All reports indicate that they are giving satisfactory service.

Report on Assignment 7

Means of Conserving Labor and Materials, Including the Adaptation of Substitute Noncritical Materials, and Specifications for the Reclamation of Released Materials, Tools and Equipment

Collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR

S. L. Goldberg (chairman, subcommittee), W. W. Boyer, T. P. Burgess, E. M. Cummings, Nelson Handsaker, H. G. Kriegel, Clifford Wendell, W. C. Wilder.

This is a final report submitted as information. Previous reports on this assignment appear in the Proceedings, Vol. 54, 1953, pages 963 to 967 incl., and in the Proceedings, Vol. 55, 1954, pages 583 and 584.

This subject was originally a war-time assignment, and the previous reports were more or less concerned with the conservation of labor and materials for wood bridges and trestles due to their short supply. These previous reports have exhausted the possibilities along these lines.

Last year the Board Committee on Outline of Work voted to drop the assignment on means of conserving labor and materials from the subject lists of those committees which carried it during the Korean War emergency. However, Committee 7 requested that this assignment be carried over one more year in order to discuss and review more fully the need for conservation in the construction and maintenance of wood bridges and trestles.

This has been done, and the committee now recommends that the subject of conservation of labor and material be dropped from the work agendum of Committee 7, and suggests that it might be approached from an economic point of view by Committee 22—Economics of Railway Labor.

Report of Committee 24—Cooperative Relations with Universities

R. J. Stone, *Chairman,*
W. H. Huffman,
Vice Chairman,
L. L. Adams

M. B. Allen
W. S. Autrey
J. B. Babcock
George Baylor
T. A. Blair
Armstrong Chinn
M. H. Corbyn
R. P. Davis
J. F. Davison
G. H. Echols
O. W. Eshbach
P. O. Ferris
C. G. Grove
W. W. Hay
J. P. Hiltz, Jr.
S. R. Hursh
A. V. Johnston
G. A. Kellow
Frank Kerekes
W. S. Kerr
H. E. Kirby
T. R. Klingel
N. W. Kopp
B. B. Lewis
F. J. Lewis
H. S. Loeffler
E. E. Mayo
G. W. Miller
C. H. Mottier
R. C. Nissen
L. M. Ogilvie
W. A. Oliver
J. F. Pearce
J. E. Perry
R. B. Rice
W. T. Rice
J. A. Rust
W. C. Sadler
P. S. Settle, Jr.
H. O. Sharp
D. W. Tilman
Barton Wheelwright
R. B. Wooters
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managements of
   (a) the importance of bringing into the service selected graduates of colleges and universities, and
   (b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

   No formal report, but a panel discussion will be presented at annual meeting.

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

   Progress report, presented as information ..... page 572

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information ..... page 574

4. Conduct a study looking to the publication of a booklet, or booklets, for distribution to educational groups, particularly high schools and undergraduates in colleges, designed to stimulate interest in the opportunities afforded in a railroad engineering career.

   Final report, submitted as information ..... page 577

The Committee on Cooperative Relations with Universities,
R. J. Stone, *Chairman.*

AREA Bulletn 527, January 1956.

Report on Assignment 2

Stimulate Among College and University Students A Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure, By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities

R. P. Davis (chairman, subcommittee), W. H. Huffman, L. L. Adams, W. S. Autrey, T. A. Blair, J. F. Davison, E. W. Falanders, E. E. Mayo, G. W. Miller, J. E. Perry, J. A. Rust, Barton Wheelwright, R. B. Wooters.

This is a progress report, submitted as information.

Among the activities sponsored by your subcommittee are included the furnishing of speakers for student groups, promoting inspection trips to railroad operations and construction work, assisting in placing students during summer vacation periods, assisting in recruitment programs, and helping the teaching profession maintain high-grade courses in the several colleges and universities in railroad or related subjects.

Following are some examples of these activities. Many more could be cited.

Quoting from a letter received from G. H. Echols, chief engineer, Southern Railway System:

"Our chief engineers, M. W. & S., namely, J. S. Wearn (Western Lines, Cincinnati, Ohio), R. B. Midkiff (Central Lines, Knoxville, Tenn.), and J. F. Beaver (Eastern Lines Charlotte, N. C.), made personal visits to representative engineering colleges in the southeast to interview prospective graduates, with a view to locating men who are interested in making railroad work their career. Where personal contacts cannot be made, the prospective graduates are advised by mail, outlining our student apprentice training program, and in that way we gain the attention and interest of prospective graduates, with beneficial results.

"Additionally, we have some jobs in our engineering department carrying the title of rodman, which we fill with students who are taking Co-op. courses, in which courses they work for us and attend college in alternating quarters of the year. Thus, we have two students filling one position as rodman. Usually, these men have become interested in railroading by the time they finish their college courses, and upon graduation they are ready to enter a student apprentice position. This is particularly satisfactory, because of the fact that while working for us during their college work they gain a good knowledge of our methods and procedures. Consequently, they already have many fundamentals of railroading digested before starting their training as student apprentices.

"We also have positions during vacation periods, i.e., June, July and August, designated as student engineers. We fill these postiions with interested students who take the regular course and who are interested in summer work. We find that after several summers of work they, too, become interested in railroading and we employ them as student apprentices after they have completed their college work."

W. W. Hay, associate professor of railway civil engineering at the University of Illinois, reported the following activities at that institution:

(1) Representatives from 8 railroads intreviewed approximately 60 students on the campus for railroad jobs.

(2) The following addresses to the senior civil engineering class were given:

(a) C. F. Nelson, industrial agent, Rock Island Lines, the subject being "New Jobs for Civil Engineers on the Railroads".

(b) C. H. Mottier, vice president and chief engineer, Illinois Central Railroad, the subject being, "The Prudential Building".

(3) The senior class in railroad construction and maintenance observed in the field the operation of a mechanized rail-laying gang on the Illinois Central Railroad.

(4) Some 10 or 12 films were secured on loan from railroads and were shown to classes in railway engineering.

(5) Twelve staff members were active in membership, convention attendance, committee work, and research with AREA.

(6) Arrangements were made for the university to act as hosts for the October (1955) meeting of Committee 24.

The following statement comes from Mr. A. V. Johnston, chief engineer, Canadian National Railways:

"It has been the practice of the Canadian National to conduct a coordinated recruiting campaign in all engineering colleges across Canada. Interview teams composed of representatives of all interested departments visit each university and interview students for both seasonal employment as undergraduates and permanent employment as graduates. Recruitment is principally for civil engineers, but some electrical or mechanical engineers are also contacted. A smaller number from other courses are contacted at the same time, but the effort is directed primarily to the engineers.

"Occasional contacts with engineering faculties are maintained throughout the year, and in some instances speakers are provided to deliver talks on prescribed subjects identified with the railway industry. The only instance known officially in this office concerns a talk given in October 1954 to approximately 180 students of Ecole Polytechnique, Montreal, during a vocational guidance session by a member of the bridge engineer's staff, on the problems of a structural designer in the railway industry. This method of creating interest in railway engineering has not been developed to any great extent yet, but it is our hope that means can be found to maintain almost continuous contacts with both faculty and student body throughout the year."

Dean Fred J. Lewis, School of Engineering, Vanderbilt University, reports that he has been in contact with all of the high and preparatory schools of the Davidson County area in Tennessee, as well as with several large vocational guidance periods established by County groups, such as those held at Austin Peay College and Tennessee Polytechnic Institute. In these contacts Professor Lewis stressed the opportunities in the public utilities fields, and particularly in the railroad industry.

J. F. Pearce, assistant to division engineer, Western Pacific Railroad, reports a summer training program established in 1951 under which a group of students from a number of institutions are employed on a 3-year program, with the objective of the company hiring the better students at the termination of their final year. This program, he states, has been quite successful, both from the standpoint of the railroad and the local universities.

Other examples of worthwhile contacts include addresses by Dean Frank Kerekes of the Michigan College of Mining and Technology before student groups of that institution; a number of addresses by W. S. Kerr, vice president and business manager, Northwestern University; attendance by H. E. Kirby, cost engineer-system, Chesapeake and Ohio Railway, at a joint meeting of ASCE student chapters at Virginia Military Academy; and an inspection trip headed by Professor H. O. Sharp, Rensselaer Polytechnic Institute, of a group of students to the Boston and Maine Railroad's Mechanicville hump yard.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

O. W. Eshbach (chairman, subcommittee), W. H. Huffman, W. S. Kerr, J. B. Babcock, Armstrong Chinn, P. O. Ferris, C. G. Grove, A. V. Johnston, T. R. Klingel, R. C. Nissen, L. M. Ogilvie, J. F. Pearce.

Part-time employment and cooperative education is the subject assigned to this subcommittee. The committee has no special report to submit relative to the participation of railways at this time, but takes this opportunity to call attention through the following monograph to the occasion of the fiftieth anniversary of cooperative education and to present certain information about its origin and the nature of its current operation.

The Fiftieth Anniversary of Cooperative Engineering Education

By Ovid W. Eshbach

Professor of Engineering Science, Northwestern Technological Institute

Usually, advances in methods of education take place gradually and unnoticed. The introduction of the cooperative idea is an exception. It is a tribute to the vision and perseverance of the late Dean Herman Schneider of the University of Cincinnati who organized and promoted the scheme at the University in 1906 against the usual opposition to innovations in traditional methods.

The circumstances or influences which precipitated the experiment were many and varied. A fairly complete account is written in the book "Ambassador to Industry," by Clyde W. Park, published by Bobbs Merrill Company, Indianapolis, Ind., and New York, 1943.

As a result of his early experience in the mining regions of Pennsylvania—his birth at Summit Hill, Pa., September 12, 1872, the influence of exceptional teachers such as W. S. Franklin and M. Merriman at Lehigh, where he was graduated in 1894, the encouragement of certain classmates, and the necessity of earning his way through college—he accepted the challenge of educational work and early arrived at the conviction that the vitality of engineering education lay in developed ability for thorough study, and the skill and courage to act in mastering the job at hand. He looked upon education and mental growth as life-long processes motivated by the environment of the established functions of our industrial, social, and economic life. He felt that to provide the type of education needed to meet the challenge of the future was a more sacred obligation than the preservation of existing organizations and concepts. In this he was opposed by the influence of vested interests and the inertia of public and educational opinion which, rooted in the past, invariably constitute retarding forces to progress. To discover that a college atmosphere does not always promote the tempo of life which makes change of ideas a natural expectation was an early discouragement. By chance and unusual circumstances he joined the engineering staff at the University of Cincinnati, and with the encouragement of its president and certain men in industry launched the scheme of cooperative education.

The initial plan was a compromise of more idealistic ideas held by its founder and consisted of many and short periods of alternate study and work during the regular academic 9-months, resulting in a 6-year course, whereas the later tendency lengthened the work and study periods, utilized the summers and resulted in a 5-year curricula.

During the first 15 years of the operation of the plan, 1906 through World War I, the enrollment of students increased from 27 to 970, and the number of participating firms from 14 to 135. In both cases, except for the influence of World War I, the growth was linear with time.

It is significant to note that up to World War I, or the beginning of the industrial expansion of the '20's, with the exception of a minority of firms, college graduates were not enthusiastically welcomed by industry. For this reason the development not only at Cincinnati, but at 10 other institutions during this period, is quite significant. The schools and approximate dates of adoption in part of the cooperative plan during this period are as follows:

University of Cincinnati	1906
Northeastern College	1909
University of Pittsburgh	1910
Georgia Institute of Technology	1912
University of Akron	1914
Marquette University	1918
Mass. Institute of Technology	1919
Harvard University	1920
Antioch College	1921
New York University	1921

At the beginning of the rapid expansion following World War I, more than 3000 students were enrolled in cooperative courses with approximately 500 firms participating. During this period and up to the depression of the '30's, a number of schools adopted the plan, among which were Drexel Institute, the University of Tennessee, Newark College of Engineering, the University of Detroit, the University of Louisville, and others.

The depression years were a real test of the practicality of the plan under the most adverse economic circumstances. A few programs were discontinued, but their educational merit had been so well established that nearly all of them are in existence today. Although only a small percentage of all engineering enrollments are in cooperative courses, their numbers have more than doubled since the early '20's and produce about 6 percent of the yearly graduates.

Having survived the obstacles of prejudice, two wars, and a severe depression, cooperative education has shown unusual health in the last decade. Of particular significance is the tendency of large state and well established institutions to experiment with the plan on a select and optional basis. Promise for the future is held in the growing recognition among industrialists that cooperative training provides an answer to the need for well adjusted and properly oriented engineers who can step into positions of responsibility shortly after graduation.

Many companies now have cooperative trainees from 15 different schools. One of the industrial problems is the coordination of the varying schedules of work periods. The Cooperative Engineering Division of the American Society for Engineering Education, at its Midwinter meeting last year, made a request for a study in the variations in cooperative calendars with the hope that a more closely coordinated calendar among the colleges would enhance the opportunity for industry to expand and improve training assignments. A careful study of these calendars and the reasons behind their planning brought about the following conclusions as reported by Donald C. Hunt of the University of Detroit, at the 1955 meeting of the ASEE at Penn State University:

1. Work periods of equal length are most desirable for industrial planning, and the vacation periods are the adjusting factors in making equal work periods.

2. As a 3-month period provides the maximum that a student should be away from school, it follows that work assignments of 13 weeks should be planned.

3. "Natural" breaks in the calendar provide the best time for rotating students, and the two most "natural" breaks are Christmas and Commencement (Easter dates are too variable to be considered).

4. An exact quarter system, rotating approximately the fourth week of September, December, March and June, is the most desirable.

5. Although variations of 3 to 4 weeks appear insignificant, it should be noted that in a 13-week plan the maximum variation is 6 weeks, and differences of more than 1 week are undesirable.

6. The request of industry for a coordinated calendar among the colleges is reasonable and sound if we are to expect continued improvements in the training programs provided for cooperative students.

7. A failure to recognize the request would be extremely impolitic as the request has come from the "customers" of cooperative education.

The degree to which present schools conform to these recommendations is given in the order of conformity to the expressed ideal as follows:

Louisville, Georgia Tech., Northwestern, Drexel, Virginia Polytechnic Institute, Minnesota, and Tennessee—Average work periods 13 weeks or 3 months. Changes occurring late September, January 1, April 1, and July 1, with minor variations of about 1 or 2 weeks.

Evansville, Marquette, Fenn, and Detroit—Average work periods of 13 weeks or 3 months. Changes occurring September 1, December 1, March 1, and June 1, with variations of about 1 week.

Cincinnati and Akron—Average work periods about 10 weeks.

General Motors Institute—Regular 4-week periods.

Northeastern, M.I.T., Illinois Tech, and Antoich—At least one period of 16 weeks or more and other periods of 8 to 14 weeks.

Appraisal of cooperative education is difficult; one has to live with it in college and industry to judge its merits. No one should attempt it without reading the life of Herman Schneider, consulting with the cooperating industries and colleges, and by all means talking to the graduates of various maturity after graduation.

A survey made in 1955 by a school whose 1700 graduates completed their education since 1944 showed that 94 percent felt that the training was of value to them, and 85 percent believed it was of sufficient value to justify the extra year in school. Of those holding the Master's Degree, about 75 percent believed it was of sufficient value to justify the extra year, even though it prolonged their graduation with an advanced degree. It is also interesting to note that while the work of many was interrupted by the war, 33 percent continued with the same company after graduation, and 85 percent of these were with the same company after several years.

Report on Assignment 4

Conduct a Study Looking to the Publication of a Booklet, or Booklets, for Distribution to Educational Groups, Particularly High Schools and Undergraduates in Colleges, Designed to Stimulate Interest in the Opportunities Afforded in a Railroad Engineering Career

Collaborating with the Mechanical Division, the Electrical Section, the Signal Section, and the Communications Section, AAR

G. A. Kellow (chairman, subcommittee), George Baylor, W. H. Huffman, W. W. Hay, S. R. Hursh, Frank Kerekes, H. E. Kirby, B. B. Lewis, H. S. Loeffler, W. A. Oliver, W. C. Sadler, H. O. Sharp.

This is a final report, submitted as information.

In last year's report the committee submitted text material to be included in a brochure designed primarily for undergraduates in colleges, and recommended that the Board of Direction give consideration to the development of this material into an attractive brochure.

With the cooperation of the Public Relations Department, AAR, a dummy brochure, together with estimates of cost based on a survey of probable distribution during the next three years, was prepared and presented to the Board of Directors. This called for an attractive, two-color, profusely illustrated, 28-page publication, 8½ by 11 in. The Board authorized the publication of 25,000 copies of the brochure, 10,000 for distribution by the Public Relations Department of the AAR, at its expense, and 150,000 for distribution by the AREA, at its expense.

The initial distribution of the Public Relations Department, AAR, included copies to:

All chief executive, chief operating, and public relations officers of AAR Member Roads;
1400 school, college, public and other libraries; and
900 college professors of transportation and allied subjects.

To date the AREA, on the basis of specific requests, has distributed approximately 4900 copies free to 182 engineering colleges and universities, and has sold more than 2700 copies to individual railroads for use in their own recruitment efforts. The AREA is also offering single copies of the brochure to high school counselors, upon request.

The assignment of Subcommittee 4 contemplated the possible development of a second booklet for distribution to high schools, but it is felt that the brochure already published and offered to high school counselors admirably meets the needs of this younger age group.

It is the recommendation of the committee, therefore, that the subject be discontinued.

Report of Committee 11—Records and Accounts

H. N. Halper, *Chairman,*

V. H. Doyle,
Vice Chairman,
B. H. Moore, *Secretary*
R. B. Aldridge
F. B. Baldwin
S. H. Barnhart
B. A. Bertenshaw (E)
H. T. Bradley
M. A. Bryant
P. D. Coons
V. R. Copp
Spencer Danby
Benjamin Elkind
D. E. Field
B. Firestone
Morton Friedman
W. S. Gates, Jr.
M. M. Gerber
W. A. Godfrey
W. M. Hager
C. C. Haire (E)
J. H. Hande (E)
L. W. Howard
R. D. Iogu
C. Jacoby*
E. M. Killough
W. A. Krauska
C. E. Lex, Jr.
W. M. Ludolph
M. F. Mannion
C. B. Martin
A. H. Meyers**
O. M. Miles
J. B. Mitchell
J. K. Morrissey
B. F. Nauert
F. H. Neely
J. H. O'Brien
C. F. Olson
W. C. Pauli
L. A. Pelton
D. E. Pergrin
M. G. Pettis
A. T. Powell
H. L. Restall
J. H. Roach
F. A. Roberts
E. J. Rockefeller
H. B. Sampson
R. L. Samuell
W. F. Sanders
J. E. Scharper
J. H. Schoonover
H. A. Shinkle
J. N. Smeaton
J. B. Styles
J. R. Traylor
H. C. Wertenberger
W. C. Wieters
J. L. Willcox
Louis Wolf
Committee

(E) Member Emeritus.
* Died March 9, 1955.
** Died June 22, 1955.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, presented as information ..... page 582

2. Bibliography on subjects pertaining to records and accounts.
   Progress report, presented as information ..... page 582

3. Office and drafting practices.
   Progress report, presented as information ..... page 595

4. Use of statistics in railway engineering.
   Final report on budgetary procedures, presented as information ..... page 599

5. Construction reports and property records.
   Final report, presented as information ..... page 620

6. Valuation and depreciation.
   (a) Current developments in connection with regulatory bodies and courts.
   Progress report, presented as information ..... page 638

(b) ICC valuation orders and reports.
Progress in study, but no report.

(c) Development of depreciation data.
Progress in study, but no report.

7. Revisions and interpretations of ICC accounting classifications.
Progress report, presented as information ..... page 641

8. Simplification of records to determine original costs of tracks to be used in their retirements from the investment account.
Progress in study, but no report.

THE COMMITTEE ON RECORDS AND ACCOUNTS,
H. N. HALPER, *Chairman.*

AREA Bulletn 527, January 1956.

MEMOIR

Cornelius Jacoby

Cornelius Jacoby, valuation engineer, Southern Railway System, died suddenly March 9, 1955. He is survived by his second wife, Lena B. Jacoby, his daughter, Mrs. Elizabeth J. Naylor, and three grandchildren. Mrs. Naylor's mother, Cecile Holt Jacoby, died in 1950.

Mr. Jacoby was born October 30, 1886, in Tadler, Luxembourg. He received his secondary school education at the State Higher School for Boys at Hildburghausen, Saxony (now Thuringia), Germany, and graduated from Polytechnic Institute (Technische Universitat), Berlin–Charlottenburg, Germany, in 1907. For a year he was engineer on the construction of the industrial high school at Metz, Lorraine, France.

Mr. Jacoby arrived in the United States of America in 1909 as a representative of the Luxembourg steel industry to study procedures and production methods developed by the steel industry in America. Subsequently, he was inspector on the construction of the Cook County Poor House at Oak Forest, Ill., and then for six months was an engineer on design and estimating for iron and metal work in St. Louis, Mo.

He first entered railway service in 1911 with the St. Louis–San Francisco Railway, serving briefly as rodman and junior engineer, then becoming masonry inspector designing masonry structures. After about a year and a half with the Frisco Lines, he joined the Cleveland, Cincinnati, Chicago & St. Louis Railway in April 1913, as resident engineer in charge of the reconstruction of a bridge over the Big Miami River (after the Dayton flood of 1913), involving heavy foundation and cofferdam work.

He joined the Southern Railway August 1, 1914, as a rodman at Danville, Va. After 4 months in this capacity he was promoted to transitman and successively promoted to various positions in the engineering department throughout the next 27 years, becoming valuation engineer in October 1941.

Mr. Jacoby was thoroughly familiar with the beginning of the work in valuation from the inception of the federal inventory and through the period of setting up records and procedures to comply with Interstate Commerce Commission Valuation Order No. 3, being in charge of this work from 1925 to 1934.

In 1914 Mr. Jacoby became a naturalized American citizen, but he retained a deep interest in the land of his birth. During both World Wars he helped organize relief for the people of his twice over-run former homeland. He was appointed counselor of the Luxembourg legation at Washington, D. C., by Grand Ducal Decree on October 21, 1924. On June 19, 1935, he was awarded "La Croix de Chevalier de l'Ordre de la Couronne de Chene" by the Luxembourg government.

He was a member of Washington Centennial Lodge No. 14, F.A.A.M., Washington, D. C., and an associate member of the American Society of Civil Engineers from 1921 to 1943.

Mr. Jacoby joined the American Railway Engineering Association in 1946 and immediately became a member of Committee 11—Records and Accounts.

His experience in railroad engineering in both field and office; his intimate knowledge of the history and development of valuation, depreciation and railroad accounting; his remarkably acute memory; and his friendly interest in the activities of his associates, endeared him to all who knew him. It is with sorrow and regret that we here record his passing.

W. M. Hager, *Chairman,*
B. H. Moore
E. J. Rockefeller
Committee on Memoir.

MEMOIR

Archibald Henry Meyers

Archibald Henry Meyers, assistant engineer—valuation, of The Texas and Pacific Railway, and chairman of Subcommittee 2—Bibliography, of Committee 11—Records and Accounts, died at Dallas, Tex., June 22, 1955.

Mr. Meyers was born January 29, 1887, at Boscobel, Wis. and was graduated from the high school at Fennimore, Wis.

He entered the service of the Texas and Pacific at Marshall shops December 4, 1906, beginning as a drill press operator, but transferred to the coach department where he served as coach builder. In April 1916 he transferred to the valuation department; on September 16, 1928, he was assigned to the position of mechanical assistant to the chief engineer; and was promoted to assistant engineer—valuation August 1, 1943. At time of his death he had worked 49 years for the railroad.

He joined the American Railway Engineering Association in 1947 and the following year became a member of Committee 11.

He is survived by three daughters, Mrs. Madeline M. Cole of Dallas, Mrs. Evelyn M. Hodde, Washington, D. C., and Mrs. Ann M. Bell, Longview, Tex. His wife died in 1942.

He was a 32nd degree Mason and Shriner and a member of the Methodist Church.

Mr. Meyers gave generously of his time to committee work and will long be remembered as a cultured gentleman, a loyal friend and an efficient worker. His many friends will mourn his passing.

H. T. Bradley
W. A. Godfrey
W. A. Krauska
Committee on Memoir.

Report on Assignment 1

Revision of Manual

W. A. Krauska (chairman, subcommittee), F. B. Baldwin, P. D. Coons, D. E. Field, C. C. Haire, E. M. Killough, W. M. Ludolph, J. B. Mitchell, J. H. O'Brien, F. A. Roberts, R. L. Samuell, W. F. Sanders, J. H. Schoonover, J. N. Smeaton.

This is a progress report presented as information.

During the past year your committee has given a great deal of attention to the material in its chapter in the AREA Manual of Recommended Practice. It has at present some 35 revisions of graphical symbols, involving pages 11–4–2 to 11–4–18, incl., under study.

Collaboration with the ASA Task Group Y32 and the AAR Signal Section Committee V was resumed with the view of coordinating further revisions being made to the graphical symbols in the AAR Signal Section Manual and the American Standards Graphical Symbols for Railroad Use, ASA Z32.25, with the symbols in the AREA Manual.

W. M. Ludolph and W. A. Krauska represent your committee on the ASA Task Group Y32 and to date have attended all the joint sessions on the coordination of graphical symbols.

Under date of September 15, 1955, all members of the American Standards Association Sectional Committee received copies of the ASA Graphical Symbols for Railroad Use, as revised by Task Group Y32, and following approval these symbols will become an American Standard.

Your committee is of the opinion that after approval of the revisions proposed by Task Group Y32, the graphical symbols in the AREA Manual, in the AAR Signal Section Manual, and the ASA Graphical Symbols for Railroad Use should be made uniform.

Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

A. H. Meyers (chairman, subcommittee), M. M. Gerber, C. E. Lex, Jr., B. H. Moore, B. F. Nauert, F. H. Neely, E. J. Rockefeller, J. E. Scharper, H. C. Wertenberger, W. C. Wieters, L. Wolf.

This report is submitted as information.

Your committee presents the following bibliography of subjects pertaining to railroad records and accounts for the period September 1954 to September 1955.

Depreciation

1. *What you Need to Know About Depreciation, by W. H. Cartner, McGraw–Hill Department of Economics, New York. Engineering and Mining Journal, Vol. 155, October 1954, pp. 80–84.*

Your company has more freedom in the handling of depreciation under the new tax law than it has had in 20 years. Through its effect on corporate tax bills, profits, and money available for modernization and expansion, the depreciation allowance can now have a decisive impact on your company's operations in the months ahead. That is why it would be well to know what new ways of handling depreciation are open and what each one has to offer.

This article will summarize these facts and also shows two charts. One chart shows

the ways to figure depreciation under the old law and the other chart shows the ways under the new law.

2. *How to Compare Old and New Depreciation Formulas, by P. Butler and G. S. Borden, Standard Oil Company of California. Engineering and Mining Journal, Vol. 155, October 1954, pp. 85 and 100.*

In order to compare the rates and periods of time required to reduce capital recoverable through depreciation to its salvage value by the diminishing balance and the straight line methods of depreciation, it was necessary to first state both methods in terms of comparable equations. The required formulas are developed in this article, also two charts showing years required to reduce base to salvage.

3. *Effect of Liberalized Methods of Depreciation Under the Internal Revenue Code of 1954 on the Electric and Gas Utility Industries. A 47 page brochure prepared by the tax department of EBASCO Services Incorporated.*

The general purpose of this report is to explore the significance of the liberalized depreciation provisions of the Internal Revenue Code of 1954 to the private electric and gas utility industries. Consideration has been given to the effect of the proposed methods of depreciation on the financing and accounting requirements in order to take full advantage of these methods of depreciation, the problems of rate making and, finally, the overall economic issues which these provisions pose to the future of the industries. Comparisons are shown based upon tax depreciation allowances determined by:

1. The straight line method
2. The declining balance method
3. The sum of the years–digits method

4. *More Liberal Depreciation Rules Under New Tax Code, By Owen Ely, financial editor, Public Utilities Fortnightly, Vol. 54, No. 10, November 11, 1954, pp. 651– 656.*

The tax department of Ebasco Services has recently prepared a 47-page brochure under the heading "Effect of Liberalized Methods of Depreciation Under the Internal Revenue Code of 1954 on the Electric and Gas Utility Industries". The present discussion is largely based on this excellent study.

5. *Depreciation Under the New Tax Law, by Robert Eisner, associate professor of economics, Northwestern University. Harvard Business Review, Vol. 33, No. 1, January–February 1955, pp. 66–74.*

Robert Eisner, whose article on depreciation under the new tax law should be an "eye-opener" to many businessmen, reports that his interest in the subject stemmed from informal arguments with tax experts over the accuracy of reported profit figures. Applying some fundamental algebra, he reached a series of exciting conclusions about the tricks which growth and depreciation play. In his article he brings the new depreciation methods allowed by law down to cases—cases that add up to billions of dollars—and points up what they mean to different types of industries and to the economy as a whole.

6. *Re: Depreciation in Investment Decisions, by Robert N. Anthony, associate professor of business administration at Harvard Business School. Harvard Business Review, Vol. 33, No. 1, January–February 1955, pp. 75–76.*

Following up Mr. Eisner's analysis (Item No. 5 above), Mr. Anthony takes a closer look at the specific impact of the new depreciation alternatives, particularly the years–digit method, on the purchase of capital assets. His helpful note, Re: Depreciation in Investment Decisions, includes a table of how to calculate the present value of a proposed capital expenditure.

7. *Depreciation versus Inflation, by Owen Ely, financial editor, Public Utilities Fortnightly. Public Utilities Fortnightly, Vol. 55, No. 2, January 12, 1955, pp. 93–96.*

The present discussion centers about the relation of the depreciation reserve to the cost of reproduction instead of original cost; in other words, the issue whether depreciation should recognize the inflationary process. Other questions reflect the impact of new methods of depreciation accrual for tax purposes in connection with (1) five year accelerated amortization of defense plant, and (2) the new methods made permissible by the Income Tax Code such as the years digits. Such methods seem to recognize the need for rapid depreciation, but the attitude of the regulatory authorities has not yet clarified this subject.

8. *Declining-Balance Depreciation, Accounting Research Bulletin No. 44, Committee on Accounting Procedure (1953–1954). The Journal of Accountancy Vol. 96, No. 6, December 1954, pp. 757–758.*

The bulletin calls attention to the fact that the declining-balance method of estimating periodic depreciation has a long history of use in England and in other countries including, to a limited extent, the United States. Interest in this method has been increased by its specific recognition for income tax purposes in the Internal Revenue Code of 1954. It further states that the declining-balance method is one of those which meets the requirements of being systematic and rational.

9. *More on Declining-Balance Depreciation and Estimated Expenses, editorial by Carman G. Blough, CPA, director of research, American Institute of Accountants. The Journal of Accountancy, February 1955, pp. 61–71.*

The editorial discusses several questions which the editor had previously discussed with quite a few prominent practicing accountants involved in the application of the general principles set forth in Accounting Research Bulletin No. 44 and the two research department articles on declining-balance depreciation and on estimated expenses and prepaid income in the December issue of the Journal. The article states that since there appeared to be substantial agreement as to the preferable practice with respect to each of the questions raised, their comments probably indicate the trend of practice that will develop in the application of the principles. The article summarized for the information of the readers the tenor of the comments received.

10. *Swedish Telephone Depreciation on Replacement Basis, by Hans A. Heimburger. Public Utilities Fortnightly, Vol. 55, No. 7, March 31, 1955, pp. 391–394.*

A communication was received by the Public Utilities Fortnightly from Hans A. Heimburger, head of the financial division of the Swedish Telecommunications Administration, which operates the telephone system in that Scandinavian country. Mr. Heimburger writes, "It might interest your readers to know that in the Swedish Telecommunications Administration allowances for depreciation are since July 1, 1951, made on the basis of the cost of replacement of installations."

Mr. Heimburger sent along an English edition of his administration's publication Tele containing an article by himself outlining the financial practices of that government utility service. This article has been digested in this issue of the Public Utilities Fortnightly.

11. *British Telephone Depreciation Practice. Public Utilities Fortnightly, Vol. 55, No. 3, 1955, pp. 159–161.*

The British Post Office had been aware for some time that the accumulation of depreciation reserves, based on installment type accruals keyed to the straight line age-life of the original cost of plant, would result in making the Post Office use up its own

capital in operation, because the depreciation reserve coverage for replacement requirements was falling progressively behind every time plant units had to be retired. British fiscal officials labeled the original cost, age-life reserve accrual practice as "unrealistic" and deliberately set about augmenting the depreciation reserve, based on original cost amortization with extra accrual, which still fell behind to some extent in taking care of continuous and progressive replacement requirements.

This view clashes, of course, with the traditional concept of depreciation accounting held sacred by many regulatory experts in the United States.

12. *The Terminal-Date-Group Method of Depreciation Accounting, by A. B. Carson, CPA and Ph.D., associate professor of accounting, University of California. The Journal of Accountancy, April 1955, pp. 56–62.*

Allocation of the cost of most long-lived assets to the periods benefited by their use is now generally recognized as an essential part of the measurement of periodic income. Various procedures are used to compute the depreciation for each period. This article describes a type of group method for the calculation of depreciation that combines many of the virtues of conventional group or composite procedures and the advantages of the unit method. The method described can be easily adapted to one type of "reducing charge" depreciation permitted by the new tax code.

The procedure under discussion is called the Terminal-Date-Group method, and the essence of it is to group the costs of the individual units according to the dates on which they are to become fully depreciated and to compute periodic depreciation on each such group using a fraction determined by reference to its terminal date.

13. *Accounting for Depreciation Under New Income Tax Methods, by AIA Research Department. The Journal of Accountancy, Vol. 98, No. 6, December 1954, pp. 741–744.*

The Internal Revenue Code of 1954 contains several new provisions as to depreciation methods. Among them is the provision that in connection with new property having a life of three or more years, a taxpayer may, without receiving special permission, adopt the declining-balance method of depreciation, using a rate not exceeding twice the straight-line rate. As an alternate he may use the sum of the years-digits method. If the declining-balance method is adopted, the taxpayer ordinarily may at any time change to the straight-line method for the allocation of the undepreciated cost (less estimated salvage value) over the estimated remaining life. This change is not possible without permission if the sum of the years-digits method is used.

This article is a presentation of the background of the problems of accounting and disclosure covered in the recently issued Accounting Research Bulletin No. 44.

14. *Rapid Tax Depreciation, by Williard F. Stanley, tax consultant. Concrete, Vol. 63, No. 3, March 1955, pp. 22–23.*

The new tax law incorporates some important benefits. Mr. Stanley advises that the possibilities of rapid tax depreciation should be carefully studied in order that the industry would fully realize the benefits it can derive under the new tax law. He further advises that you get familiar with the financial assistance it affords and the economic gain it can bring you. This article discusses a number of important aspects of this subject.

15. *Depreciation Dons a New Look, by William H. Chartner and Edward T. Thompson. Chemical Engineering, Vol. 61, No. 12, December 1954, pp. 171–174.*

Important new depreciation formulas that allow faster write-offs in the early years of a plant's life are sure to swell industry's reserves and provide extra cash for more expansion. This paper is a discussion of the various methods of depreciation allowable

under the new tax law. It also stresses that it is essential for you as an engineer to know just what depreciation formulas are now legal and what each can accomplish in the way of bigger reserves and lower taxes.

16. *Internal Revenue Issues Tentative Regulations for Plant Depreciation. Concrete, Vol. 62, No. 11, November 1954, p. 38.*

The Internal Revenue Service has issued tentative regulations covering tax deductions for depreciation of plant and equipment. The proposed rules cover a major section in the Revenue Law of 1954 passed by Congress this summer. That law made hundreds of changes in the nation's tax system, many of them technical and highly complicated. The 26 pages of regulations on new depreciation rules for companies and individuals were published in the Federal Register dated September 28, 1954.

17. *Effect of the New Tax Law on Equipment Replacement, by William Meyers, attorney and CPA, Schartz & Meyers, New York. Machinery Vol. 61, No. 2, October 1954, pp. 200–203.*

Mr. Meyers discusses the good sense of replacing machinery frequently rather than keeping it for its useful life. The new tax law enacted by Congress makes this advice important because of the new methods of depreciation. The substantial sums of money that now can be deducted for depreciation during the early life of equipment permit a far more rapid restoration of the financial reserves than before.

The article also contains tables and application of several methods of depreciation and also a discussion of determination of useful life.

18. *Depreciation on a Current Basis, by George H. Warner, Pennsylvania State University. The Accounting Review, Vol. 29, No. 4, October 1954, pp. 628–633.*

With the marked price fluctuations of the past 15 years there has been a wealth of material written by the economist, the accountant and the business executive concerning the adequacies and inadequacies of presently accepted accounting methods of determining income. In regard to this problem a study was made in order to determine the consequences of price level charges on one element of cost depreciation and thereby their effect on net income. An effort has been made to demonstrate how net income would have varied for a few representative firms if depreciation had been calculated on a current dollar basis rather than a legal dollar basis.

19. *New Tax Law Promises Greater Capital Investment Expansion, by Curtis Fuller, editor, Industrial Marketing Annual Market Data & Directory Number, Vol. 39, No. 9, September 1954, pp. 65–67.*

This article deals with the new tax law, and it is the opinion of the editor that by allowing more realistic depreciation policies the new tax law at a minimum establishes a sounder basis for machinery, write-off, new equipment reserves, and ultimately sounder purchasing policies. In addition, the law is expected to encourage increased buying immediately in selected industries. He also discusses the application of several depreciation methods and their effect on industry.

20. *Accelerated Depreciation Allowance as a Stimulus to Investment, by Richard Goode, International Monetary Fund. The Quarterly Journal of Economics, Vol. LXIX, No. 2, May 1955, pp. 191–220.*

I. General discussion, normal and accelerated depreciation allowances, p. 192; influence on investment, p. 194; factors affecting influence of accelerated depreciation, p. 201; revenue effects, p. 203; comparison with reduction of tax rates, p. 204; accelerated depreciation as an alternate to other tax concessions in under-developed countries, p. 207; comparison with reduction of interest rates, p. 209.

II. Comparison of accelerated depreciation methods, p. 211; use of methods, p. 212; annual charges and their present value, p. 213; appraisal, p. 218.

III. Conclusion, p. 219.

21. *Accelerated Depreciation: Some Further Thoughts, by Robert Eisner and rejoiner by Evsey D. Domar. The Quarterly Journal of Economics, Vol. LXIX, No. 2, May 1955, p. 285–304.*

In this article Mr. Eisner states that accelerated depreciation has the somewhat surprising effect of increasing permanently the annual flow of depreciation charges. Accelerated depreciation may thus effect income in several distinct respects.

First, it transports depreciation charges for given assets on the average to an earlier period of time.

Second, during the very substantial period of transition to accelerated depreciation (that is, while regular depreciation charges on older properties are added to the accelerated depreciation charges on new assets, a matter of 30 or more years for many firms) accelerated depreciation raises depreciation charges and reduces taxable income.

Third, in the case of firms where the stream of gross investment is growing, it raises depreciation charges, reduces taxable income and hence reduces corporate income taxes permanently (for as long as the growth assumption obtains).

22. *Faster Depreciation; The Glitter Is Not All Gold, by I. W. Keller, NACA Bulletin 36, April 1955, pp. 1027–1040.*

23. *Effect on Taxes and Income of the New Tax Allowance for Depreciation, by Alvin Brown. NYCPA, October 1954, pp. 631–638.*

24. *Composite Depreciation Under the Sum-of-the-Digits Method, by Jacob Heskes, NYCPA, November 1954, pp. 688–692.*

Accelerated Amortization

1. *Accelerated Amortization of Defense Facilities in Annual Reports, by John H. Meyers, Ph.D., CPA, associate professor of accounting, School of Commerce, Northwestern University. The Journal of Accountancy, February 1955, pp. 52–54.*

The reader of a corporate annual report easily can become confused over the situation created by the allowance for tax purposes of accelerated amortization of emergency facilities. Some of the companies take the amortization for general reporting purposes as well as for taxes. Others show only the normal depreciation; they then set up as expense and liability the taxes that are saved now by the accelerated amortization but have to be paid later when the property is still in use but fully amortized. Since the second method more accurately reflects current income, the committee on accounting procedure in Accounting Research Bulletin No. 43 (p. 75) recommends its use where the difference between the two methods would be material.

This study is based on a review of over 200 annual reports.

2. *What the New Rapid Tax Depreciation Means to Utilities, by Willard F. Stanley, president, Corporate Services, Inc., New York. Public Utilities Fortnightly Vol. 55, No. 5, March 3, 1955, pp. 235–244.*

Mr. Stanley expresses the opinion that the subject of rapid depreciation is one of the most timely and important factors in the American economy because of its high and substantial rate expansion, particularly so for the utility industry. This is more important than the relatively temporary accelerated amortization of emergency facilities, for it is to continue permanently and will apply, if desired, to all classes of new property additions.

Accelerated amortization was admittedly a temporary expedient to meet a special defense effort, whereas rapid depreciation has been enacted as basic income tax law, as permanent as that law can ever be. The period of the higher deductions is not arbitrarily limited to 5 years, but in case of utilities will cover 16 years, if the total life span is 33 years. The continuous nature of utility expansion tends greatly to further enhance the recurring character of rapid depreciation.

Life Expectancy

1. *Life Expectancy of Steam Plant Equipment, by John J. Reilly, chief appraisal engineer, EBASCO Services, Inc., New York. Proceedings, American Society of Civil Engineers, Vol. 81, Separate No. 640, March 1955, pp. 1–8.*

Engineers are often required to make estimates of life expectancy of modern steam plant equipment. This paper describes the development and application to industrial property of various methods of statistical analysis and their use as an aid to judgement in connection with such estimates with many references. There is discussion of the units to be used and of the three basic actuarial methods: Gompertz–Makeham formula, Iowa State College (Winfrey's) survivor curves, and retirement ratios, which seem to be basic in 1955, and the combining of results of those studies and other considerations in weighing past and future in arriving at an indicated life range.

While the specific application is to steam plant equipment, the same handling presumably could be given to any other utility property where the retirement history is so short as to result in a stub survivor curve.

Cost

1. *ICC Reissues Statement on Costs. November 1954.*

The Interstate Commerce Commission's Bureau of Accounts, Cost Finding and Valuation has reissued with some revisions its "Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs."

The new issue is statement No. 4–54 of the Bureau. It bears the usual disclaimer saying it "has not been considered or adopted by the commission."

2. *Depreciation, Capital Cost Allowances and Income Taxes. Research Bulletin No. 10, issued September 1954 by Canadian Institute of Chartered Accountants. The Canadian Chartered Accountant, December 1954, pp. 349–353.*

For a number of years Canadian tax law has granted capital cost allowances somewhat similar to our new depreciation and our accelerated amortization; however, before 1954 the allowance for tax purposes was limited to the amount charged on the books. That limitation has now been lifted, and the Canadians are faced with the same problems in reporting net income as we are. Their new Research Bulletin No. 10 states the Canadian Institute's opinion on how to handle this problem and the accompanying article by Lawrence G. MacPherson, research director of the institute, discusses the article.

3. *An Economic Appraisal of the Private Electric Utility Industry, by C. P. Guercken, assistant to vice president, EBASCO Services, Inc. Public Utilities Fortnightly, Vol. 55, No. 13, June 23, 1955, pp. 739–754.*

Here is an impressive survey of various economic indicia which indicate that continued adherence to original cost concepts has produced an end result which is unrealistic in the light of actual developments. This author's suggested remedy to bring the regulatory components in the rate fixing process into proper balance is estimated at a cost to the average consumer of about 5 cents per day—a small sum to rectify what he considers a serious difficulty in regulatory policy.

4. *What is needed to Establish Reproduction Cost New, by Ralph L. Berry. NACA Bulletin, Sec. 1, September 1954, pp. 11–19.*

5. *Cost Control Numbers for Engineering Department Costs, by D. S. Mitchell, NACA Bulletin, Vol. 36, December 1954, pp. 350–357.*

6. *New Look at Historical Costs vs Current Costs, by Thomas G. Higgins. Arthur Young Journal, October 1954, pp. 1–17.*

7. *Methods of Measuring and Controlling Distribution of Costs, by H. E. Gannon, Jr. NACA Bulletin, Vol. 36, March 1955, pp. 931–939.*

8. *Costing of Fixed Assets, Review of Considerations, by T. A. Wheeler. NACA Bulletin, Vol. 36, October 1954, pp. 234–241.*

Price Level

1. *Accounting and the Price Level, by D. A. Ferguson, associate professor, Syracuse University. The Accounting Review, Vol. 29, No. 4, October 1954, pp. 639–642.*

During the last decade accountants have become increasingly aware of the effects produced on accounting statements by the substantial change that has occured in price levels. It is reasonable to expect that they should also show some interest in proposals aimed at adoption of a policy of stabilization of the price level, even though implementation of such a policy would call for action primarily in the somewhat alien field of monetary and fiscal affairs.

Mr. Ferguson suggests that so far as corporate management is concerned the accountant's primary function must be to provide information which will be useful in the making of decisions or choosing among alternatives in such a way as to maximize owner's profits and incidentally attain the socially desirable objective of making the best use of our economy's scarce resources.

2. *Price-Level Adjustments: Fetish in Accounting, by Raymond C. Dein, professor, University of Nebraska. The Accounting Review, Vol. XXX, No. 1, January 1955, pp. 3–24.*

Mr. Dein advises that the purpose of his study has been to focus attention on the need for a complete re-examination of the problem of "adjusting" to the new frame of financial reference which is implied with any substantial change in the value of money. With no more progress to show after so much time and effort as has been spent on financial statements which have been adjusted on the Sweeney model, it should be evident that the problem requires attack from a different angle. One such promising lead is suggested in a quotation from Greer—that the justice of relative distributive shares cannot ever be determined from financial statements, much less in a period of inflation.

3. *The Price-Level Study of the American Accounting Association, by Perry Mason, American Institute of Accountants. The Accounting Review, Vol. XXX, No. 1, January 1955, pp. 37–44.*

Four large companies were included in the price level study, and the period studied in general was the decade 1941 to 1951, during which inflation had been most pronounced. The general procedure followed in the project was to restate the financial statements for each company so as to eliminate, so far as possible, the effect of the change in the price level, or to express each item in terms of the value of the dollar of some one date or period. The average dollar for December 1951 was selected for this purpose.

Research

1. *Should Railroads Have Research Departments?, by Robert R. Crane, director of operations research, Westinghouse Air Brake Company, Modern Railroads, Vol. 10, No. 4, April 1955, pp. 119–124.*

A question which frequently is discussed by the railroads is whether or not they should have research dpeartments similar to those of many other industries in the United States. Other businesses consider them indispensable, but the opposite is true of the railroads. Their answer to this question has usually been in the negative. A number of reasons are given. One is that the large research establishments of other industries exist primarily because of product research while the raliroads are service organizations without specific products. Another is that the railroads are already carrying on sufficient research on the railroads and in the many activities sponsored by the railroads, such as the AAR's Research Center.

A researcher who knows railroad problems intimately analyzes this paradox.

Machine Accounting

1. *What Gains from Computers. Railway Age, Vol. 138, No. 12, March 21, 1955, pp. 52–53.*

This article is a digest of statements heard at a special conference of the American Management Association in New York, February 28, March 1 and 2, on the subject "A Practical Approach to Electronics".

Gains from use of electronic computors include better control of operations, less costly paper work and enhanced ability to meet competition. What various industries, including an important railroad, are learning about this spectacular recent development in data processing was impressed on a special American Management Association conference. It was also stressed that the improved management controls made possible by the timely, digested information the computer turns out will be far more important to business than the clerical cost savings.

2. *Auditing, Control and Electronics, A Pioneering Evaluation of the Impact of Electronics, by A. B. Toan, Jr., partner in the management advisory division of Price Waterhouse & Company. The Journal of Accountancy, May 1955, pp. 40–45.*

Manufacturers and other potential users are intensely interested in how controllers and accounting officials, as well as auditors, are to fulfill their responsibilities in the new data processing era. While practical experience with these machines may lead to some modification of existing ideas, there are already sufficient indications of what the problems are and what the solutions may be to warrant a preliminary discussion.

The title of this article is meant to suggest the interaction of the machine and audit control and to provide a basis for discussing the areas in which the interaction may be greatest and how some of the problems raised by it may be solved.

3. *Economics of the Digital Computor. Costs-Uses-Speed-Scale, by Richard F. Clippinger, chief of the computing services section, Computer Department, Raytheon Manufacturing Company. Harvard Business Review, Vol. 33, No. 1, January–February 1955, pp. 77–88.*

This article is based on wide experience in the application of high-speed automatic computers to the solution of scientific, engineering, and operations research problems and on extensive consideration of the use of computers in business and industry. It should be stressed, however, that many of the applications discussed in this article do not belong to the category of examples which have already been worked through to completion.

Thus the conclusions set forth here represent exterpolations from a broad base of experience into the future. There has been substantial demand for a more specific prediction of fields and methods of application and detail requirements of personnel and cost. It is hoped by the author that these objectives are met in this article, even though there is a risk of over simplification and consequent misinterpretation.

4. *Electronic Computers: Objective appraisal and commonsense advice, especially for managements just beginning to investigate the field. A progress report by Peter B. Laubach and Laurence E. Thompson, Harvard Business School. Harvard Business Review, Vol. 33, No. 2, March–April 1955, pp. 120–128.*

The comments in the report add up to the fact that a company management cannot sit back and judge whether or not electronic data processing will be beneficial to it on the basis of experience of other companies. Merely superficial knowledge can be acquired by reading literature and talking to users of electronic equpiment. It is only by the painful process of digging into the logics of computors and by arduous planning and working through applications that sound decisions can be made on electronic data processing for a particular company. This all requires much time and, therefore, it is not too soon to begin an investigation of the field.

The report further comments that the revolution, if that is what it is to be, appears to be off to a faltering start. Too much was promised too fast, with the result that many businessmen have grown skeptical of the entire electronic data-processing field.

5. *Electronic Equipment, and Introduction to Electronic Accounting, by R. Hunt Brown, Illinois Certified Public Accountant, December 1954, p. 2.*

This is an introduction to the new electronic equipment which may further relieve man of routine mental labor just as other machines have relieved him of routine physical labor. Accountants and auditors will not be replaced but will be affected by these new machines. An acquaintance with them is, therefore, imperative.

Efficiency of Operation

1. *Production Through Automation. Track and Structures, Vol. 51, No. 3, March 1955, pp. 70–74.*

Track raising and tie renewal gang, utilizing 10 machines and 27 men, including a foreman, approaches the ultimate in mechanization. The gang is characterized by the use of machines and men in such combinations as to achieve a balanced organization, that is, one in which the different elements progress at a uniform rate with minimum of waste motion or lost time anywhere along the line.

At the top of the article is a schematic silhouette diagram of the entire organization. Supplementing the diagram, the photographs show in numbered sequence the principal machines and operations.

2. *Daily Maintenance Cost Control—The Foremen's Tool, by W. B. Carter, general superintendent of maintenance, Allen Wood Steel Company. Iron and Steel Engineer, Vol. 31, No. 9, September 1954, pp. 123–127.*

This is the story of the development of a daily cost control system for the maintenance foreman.

The initial step in daily cost control was to create a practical work request system which would accomplish three things: first, limit the use of cost codes to persons authorized to spend the money, second, provide a systematic approach to the backlog of work and insure getting "first things first"; third, provide a method for reporting and tabulating the results.

The article contains a number of report form and punch card suggestions. Mr. Carter advises that a great deal of the clerical work can be elimniated by setting up cost control on business machines.

3. Cost control Programs, by R. H. Johnson. American Gas Association Monthly, Vol. 37, April 1955, pp. 21–23.

Rate Regulation

1. Has Regulation Veered from its Objective? Public Utilities Fortnightly, Vol. 54, No. 13, December 23, 1954, pp. 830–839.

This article is a review of a recent address by F. Warren Brooks, vice president of Cleveland Electric Illuminating Company, presented at the Irving Trust Company's public utility seminar. Mr. Brooks suggests that current regulatory formula and practices employed in fixing rates "have moved so far away from the fundamental basis justifying the existence of regulation that this basis is scarcely discernible in much of the operation of the regulatory process today."

Some outstanding early cases indicate that while fair regulation has been and always will be a difficult process, it is not impossible. The Smyth v. Ames decision, Mr. Brooks said, was a real step in the direction of sound economics in public utility regulation. Subsequent court decisions strengthened the regulatory philosophy implicit in Smyth v. Ames.

2. A Fair Return for a Natural Gas Utility, by Milford Springer, general counsel, Southern Counties Gas Company of California. Public Utilities Fortnightly, Vol. 54, No. 8, October 14, 1954, pp. 500–506.

Investor confidence, prompt and adequate service, capital attraction, system expansion, compensatory rates, adequate earnings—the full complement of elements which put together make for a strong industry—are analyzed in this article with particular emphasis on the state commission. The article states further that financial strength is required to insure the confidence of investors in the basic earning capacity of the capital that is already invested in the utility and to attract the necessary amount of new capital on reasonable terms to provide for additions and replacements of facilities.

Miscellaneous

1. Joint Equipment Committee (Report on) Cost of Railroad Equipment and Machinery, July 1, 1955. Association of American Railroads, Finance, Accounting, Taxation and Valuation Department, Transportation Building, Washington 6, D. C.

Brings up to date (through 1954) the report on historical costs of locomotives, freight cars and passenger cars and average relationship costs on various types of equipment and machinery.

2. Railroad Construction Indices, 1914–1954. Compiled by the Engineering Section of the Bureau of Accounts, Cost Finding and Valuation of the Interstate Commerce Commission, Washington, D. C., August 1, 1955.

These indices summarize and record the result of studies made by the Engineering Section of the Bureau of Accounts, Cost Finding and Valuation over a period of years. They have not been examined or passed on by the Interstate Commerce Commission.

Books

1. New Rapid Tax Depreciation—How to Use it Profitably, by Willard F. Stanley.

Prentice–Hall brings you a practical guide to the new rapid tax depreciation methods and how to use them for maximum benefit, not only from the standpoint of mini-

mizing taxes, but also from the point of accounting, financing, and the general welfare of the business. To save you time the book includes numerous examples completely worked out, plus over 100 monthly and annual depreciation tables. 153 pages, price $15.00.

2. *Herr's Depreciation Tables.*

Exact depreciation figures are instantly findable for any year, any month, partial year, or any life span. The three depreciation methods—sum of years—digits method, declining-balance, straight line—are displayed in adjacent columns so they can be compared in advance. Also included is a detailed analysis and explanation of how the new provisions work by the well known tax authority, Brady O. Bryson, attorney, of Chapman, Bryson, Walsh & O'Connell, New York. 250 pages. Sent on approval by Fallon Publications, 443 Fourth Avenue, Dept. A, New York City. Price $6.00.

3. *Railroad Accounting and Statistics—Research and Fact Finding as Aids to Management by Edward H. Bunnell, retired vice president, Finance, Accounting, Taxation and Valuation Department, Association of American Railroads.*

Nearing the end of a long illustrious career, Mr. Bunnell realized the great need for a single comprehensive book on all aspects of railroad accounting, statistics and record keeping. None existed, so he set out to prepare such a volume while a vice president of the AAR.

He included detailed explanations of all important accounts. All important forms are clearly illustrated. He wrote a brilliant interpretive analysis of accounting practice, relating it not only to pure railroad accounting activity but to other forms of railroad management and operation. Many other railroad authorities were consulted in preparing this analysis. 272 pages. Published by Watson Publications, publishers of Modern Railroads. Price $6.00.

4. *Depreciation, by Eugene L. Grant and Paul T. Norton, Jr.*

New revised printing of this authoritative volume for accountants, industrial engineers and everyone concerned with depreciation problems. Includes all major changes under the 1954 Revenue Code. Shows how alternative types of depreciation policy work in actual practice. Guides taxpayers in deciding which of the methods now permissible best suited different situations. Includes sum of years digits tables, declining-balance tables, and helpful examples from varied industries. 500 pages, 67 illustrations, tables. Price $7.50.

5. *Analysis of Railroad Operations, Second Edition, by Joseph L. White, former O.D.T. executive officer.*

This expert interpretation of ICC accounting classification will be helpful to anyone who needs to learn where railroad operations information may be found and how it is compiled. It is especially helpful to officers and department heads who are called upon to prepare explanatory presentations. Security analysts and dealers will find in the book helpful methods for compiling reports on earning power and operating prospects.

This book contains 246 pages, plus illustrated appendix, and also many charts and tables. Railway Age Books. Price $3.00.

Court Decisions

1. *Chicago v. Illinois Commerce Commission, 123 NE 2d 500, November 18, 1954. Return on present value.* The Illinois Supreme Court in finding that the commission's allowance of a return of 5.2 per cent was both reasonable and proper under the facts disclosed with regard to values and economic conditions, declared that the company should earn its return on present value rather than upon original cost of property.

2. *Re Home Light & Power Company. Application No. 12893, decision No. 43938, January 27, 1955. Return Allowance.* The Colorado commission in authorizing an electric company to increase its rates considered a return of 6.32 percent on the original cost rate base fair.

3. *Re Chesapeake & Potomac Telephone Co. PUC No. 1812/56, formal case No. 430, order No. 4096, July 29, 1954.* Inflation recognized in rate fixing in telephone company's application for approval of intrastate increases.

4. *Re Southern California Edison Co. Application No. 33952, decision No. 50449, August 17, 1954.* Rate increase reflects higher income taxes and inflation.

5. *Milwaukee & Suburban Transport Corp. v. Wisconsin Public Service Commission, 68 NW 2d, 552. Supreme Court of Wisconsin, February 8, 1955.* Depreciation computed on investment cost to purchases instead of original cost upheld by court.

6. *Regulatory Trends. Public Utilities, Vol. 55, No. 13, June 23, 1955, pp. 795–798.*

New York has moved closer to the fair value states as the result of the decision rendered May 25 by the appellate division of the state supreme court by a divided opinion (3 to 2), overturning commission orders in the New York Telephone Company rate case reported in 5 PUR 3d 33. The commission had rejected a proposed rate increase and, as a basis for its decision, had used an original cost rate base. The court's decision rests upon an interpretation of a statute relating to telephone and railroad companies which differs from statutes governing other types of utilities. Consequently, if this decision is upheld by the Court of Appeals, New York, in the absence of legislative action, may be only partly a fair value state.

7. *Reproduction Cost Not Accorded Proper Weight in Fixing Fair Value Rate Case. Public Utilities Fortnightly, Vol. 55, No. 13, June 23, 1955, p. 799.*

Re Diamond State Telephone Company, April 20, 1955. Upon reargument of points considered in a previous decision, the Delaware Supreme Court held that the fair value determination by the commission did not give sufficient weight to reproduction cost. A previous holding (5 PUR 3d 493) that although the commission erred in rejecting any allowance for cash working capital, the lower court should not have determined the amount, was re-affirmed.

8. *In the case of the Denver & Salt Lake Railway Company v. Commissioner of Internal Revenue, Docket 43783, decided July 29, 1955,* the Tax Court of the United States held that the Commissioner erred in reducing the computations of losses for depreciation occurring prior to 1943 on casualties and sudden obsolescence. This decision dealt with the deduction of the 30 percent past depreciation under the terms letter.

Depreciation Methods

The National Industrial Conference Board recently made a survey of the depreciation methods being used by 167 manufacturing companies. About half were changing their depreciation policies to take advantage of the accelerated depreciation methods now permitted under the new revenue code. Thirty five percent of the cooperating firms have definitely decided against a change from their present policy, although many point out that they can always exercise the option later if changing conditions warrant. The remaining companies have deferred a decision pending completion of studies that are under way.

Although accelerated depreciation was written into the code to stimulate plant expansion and modernization, the National Industrial Conference Board found that two-thirds of the 75 companies which have changed their depreciation policy report that the change will have no influence on their capital spending. Factors such as a demand

for products, advantages of technological improvements and the availability of cash are expected to remain the dominant considerations. In general, those companies which feel that accelerated depreciation will stimulate their capital expenditures expect to increase outlays for modernizing their plants and equipment rather than for expanding plant facilities. According to the survey, firms making a change are doing so only after careful investigation of the effect of accelerated depreciation on a long term company operation. Reporting companies favor the sum of the years digits method by a two to one margin over alternate methods.

The conference Board found that those companies which have decided against a change have done so because of the following factors: the value of new equipment is small; the nature of the equipment does not lend itself to accelerated depreciation; apprehension over the Internal Revenue Services' interpretation of the new law; the desire for a stable rate of write-offs; the preference not to gamble on tax rates; and satisfaction with the straight-line method. Many of the firms retaining their present depreciation policy indicate that their policies are not frozen. Some companies plan to review their deprecaition methods as new acquisitions are made. Other firms say they will watch tax rates and tax decisions closely. Some manufacturers may avail themselves of acceleration when their emergency facilities are completely written off.

Twenty-five percent of the companies planning to change their depreciation methods foresee some change in their practice of differentiating between depreciation accounting for tax and book purposes. On the one hand, some companies favoring a "conservative" approach will maintain their accounts on a straight-line basis for internal purposes and take accelerated depreciation solely for tax purposes. On the other hand, some companies that have previously been writing off assets at a faster rate for internal purposes forsee eventual reconciliation in the two accounts.

News Report

A Resume of the Month's Major Events, *The Journal of Accountancy, April 1955, pp. 14–15.*

Report on Assignment 3

Office and Drafting Practices

W. M. Ludolph (chairman, subcommittee), B. Elkind, D. E. Field, W. A. Krauska, A. H. Meyers, L. A. Pelton, A. T. Powell, H. B. Sampson, R. L. Samuell, J. H. Schoonover, H. A. Shinkle, J. R. Traylor, W. C. Wieters.

Recently, considerable interest has been expressed in reducing costs in drafting rooms and offices of the engineering departments of railroads as well as of other industries. Much of this can be accomplished by the use of proper processes of duplicating records.

Duplication falls into the following general classes:

1. Printing
2. Transfer processes
3. Photographic reproductions
   a. Contact
      (1) Direct
      (2) Reflex
   b. Projection
4. Thermal sensitive paper

1. Printing

Type Set by Professional Printers. This method is usually used for reproduction of forms, general instruction books, and so on, when a large number of copies are required. This is usually the most economical method for quantities over 1000.

Lithograph. This process is not used very much at present as it has been superseded for the most part by offset printing. It was used for reproduction of standard drawings and exhibits where several hundred copies were required; also for reproducing maps on tracing cloth. This work was done by professional printers.

Offset Printing. This process is in extensive use where a large number of copies of records of various kinds are required, such as general letters of instructions, standard drawings, etc. In fact, this method has been so much simplified that typing with a special typewriter ribbon can be done on a chemically treated cardboard or metal sheet, after which the sheet or plate is again chemically treated so that the printers ink adheres only to the portion covered by the ink from the typewriter ribbon. This sheet can then be used in a rotary or flat-type printing press, and practically an unlimited number of copies can be produced.

Line drawings can also be made on this material and reproduced in a like manner by the use of a special drafting ink.

Stencils. This is probably the most common and cheapest method of producing a medium number of copies, the stencils can be cut on a typewriter and run on a rotary machine, either hand or electrically driven, and the copies can be made in a short time.

2. Transfer Processes

Copy Press. This is an obsolete type of reproduction as it required the original to be written with a copying pencil or copying ink which contained a very strong aniline dye, and paper through which the aniline dye would penetrate when subjected to moisture and pressure. This was used to make only a few copies.

Gelatin Plates. In this method the original is made with a copying ink, pencil or copying typewriter ribbon. The original is then pressed into the gelatin plate where it leaves an image. From this image a number of copies can be made by pressing on sheets of special finish paper one at a time.

Various colored inks and pencils are available for this process, and it is possible to have as many as four colors reproduced at the same time.

Spirit Transfer. In this method the original is carbon backed with a copy carbon. The original is then placed in a machine with a rotary revolving cylinder. A special-type paper is used, and either the original or the paper is moistened with denatured alcohol or some other spirit which, in turn, transfers the carbon typing to the transfer paper. This is quite a rapid progress, but the number of copies obtainable is limited.

3. Photographic Reproduction Processes

Blueprint. The blueprint is the oldest of the photographic reproduction processes used in drafting rooms and consists of exposing paper or other media coated with an emulsion containing potassium ferrocyanide and potassium ferricyanide to a light source for the proper period, then developing the image in an oxidizing agent, such as potassium bichromate or hydrogen peroxide, then washing out the developing agent and drying.

Diazo Dye Emulsion. In this process paper is coated with a dye-coupled emulsion which is light sensitive. When subjected to a strong alkali the portions exposed to the light bleach out and on account of neutralization of the acid in the dye-coupled emulsion, the portions not exposed to light will be dyed a dark color and produce a positive image.

That is, black lines on the original will be dark lines on the copy. There are several colors available in this process, namely, black, sepia and blue.

There are two methods of developing these prints: one is by passing them through a chamber of ammonia vapor and the other is by applying a small amount of solution which only moistens the surface of the print.

These diazo dye emulsions can be coated on several media, such as regular weight paper, lightweight paper, plastic film, etc.

Silver-Coated Media. There is a wide variation in the media which can be coated and also the purpose of the coating. These media vary from heavy card paper to tracing cloth. All of these media require either a liquid developer or a developer which will place a considerable amount of moisture on the print and either a liquid or some other means of neutralizing the developing action.

This process is usually limited to small-size drawings or other small material to be copied. However, in the case of the Van Dyke or sepia papers, large sizes are often made for producing positive line silver prints on tracing cloth or translucent paper.

These silver-coated media are very often used for making reflex prints from opaque material or material which is printed on both sides, such as the pages of a book. The process is the same except that the paper is placed with the sensitized side toward the material to be copied and the light source is to the back of the media on which the copy is to be made.

Equipment for Making Contact Prints. Originally the sun frame, consisting of a glass and a means to hold the glass in place, was used, and the tracing or translucent material to be copied was placed next to the glass with sensitized paper behind it. Next, the frame was closed up with padding back of the sensitized paper and between it and the rigid back. Then the frame was set in the sun for the proper length of time to expose the material, after which it was removed and developed.

The next development in connection with the processing of light-sensitive contact prints was the vacuum frame. This is essentially the same as the sun frame except that a vacuum is pumped between the padding or cushion and the original to be copied and the sensitized paper so that there will be an absolute contact. This frame is sometimes used in the sun but more often powerful arc lights are used to expose the material.

The next development was for sheet processing, which consisted of a machine with a light source surrounded or partly surrounded by a glass cylinder over which the translucent original and sensitized paper were moved by the use of a canvas belt. These machines are usually small desk units and are intended only for occasional use where a small amount of reproduction is to be done.

Where a large amount of reproduction is to be done, a continuous machine is usually used. In the case of blueprinting this consists of an exposure section similar to the smaller machine. That is, the light source is surrounded or partly surrounded by glass. After passing through the exposure section, the paper is continued without cutting through a developing solution usually flowed on vertically. In the next cycle the developer is washed off, after which the paper passes over drying rollers or coils and is finally put into a roll. For machines for processing the diazo dye emulsion, the process is the same, except that instead of the print being put through a liquid developer and washer, it is passed through a housing containing ammonia fumes. In the case of papers to be processed by a liquid, the paper is passed through a series of steel rollers which are coated with the liquid from rubber rollers running in the solution.

Projection Printing. This method has the big advantage that reproductions can be made to practically any scale regardless of the scale of the original, except that too great

a difference will affect the legibility of the print. The simplest of these machines, commonly known as a photostat machine, consists of a camera, a right-angle prism and a copyboard, and produces a negative on paper. If a positive print is required, the negative first produced is used in place of the original on the copyboard which will produce a positive print in the camera. These machines require a liquid developer and fixer and are equipped so that when the paper has been properly exposed, it is automatically put into the developing chamber, agitated, and put into the fixing chamber for the final operation, after which it must be taken out, properly washed and dried. Usually a rotary dryer is used, consisting of a canvas belt driving a revolving heated drum, and by the time the drum makes one revolution, the prints placed between the canvas belt and the drum are dry.

The next method is a camera and enlarger or viewer. This process is essentially the same as the previous one, except that film is usually used for the negative and the prints produced by projection with an enlarger. This includes microfilming, in which case the microfilm is usually processed by a special laboratory, although there is equipment available for processing it in the customer's premises.

Another machine of considerable interest is one which will photograph long drawings on microfilm and which will also produce copies of the drawings at full size, or one-half, or one-quarter their original size. This machine is very expensive as it is necessary to electronically control both the speeds of the drawing photographed and the film, in order to maintain register. Also, when prints are being made, it is necessary to electronically control the speed of the paper on which the print is being made. In addition, an auxiliary developing and fixing machine and other apparatus are required.

At the present time there are only a few of these machines in the United States. If one of these machines were available at a blue printer in the locality, small-scale prints of yard layouts, track elevation plans or other exhibits could be made without the necessity of pasting photoprints together.

4. Thermal Sensitive Paper

This process is probably the most versatile and convenient of any of the processes, as opaque material as well as translucent material can be copied. The machine for this purpose consists essentially of a series of belts on rollers which pass the original and paper past an electric heating unit.

This machine produces a positive image on the coated paper which is permanent unless subjected to a high temperature.

This report is submitted as information, and it is expected that it will be rewritten in condensed form for inclusion in the Manual in place of Art. 20—Blueprint Reproductions, of the Specifications for the Design, Arrangement and Printing of Forms, Part 1, Chapter 11.

W. A. Krauska and W. M. Ludolph of this committee, together with F. Youngwert and E. B. Platt of the Signal Section, Association American Railroads, have been working as a Task Group of American Standards Committee Y32 in preparing American Standard Y 32.2.5, Graphical Symbols for Railroad Use.

W. M. Ludolph of this Committee, as AAR representative on American Standards Association Committee Y14, has been collaborating with other sections of the AAR in furnishing comments in connection with the preparation of the Proposed American Drafting Standards Manual.

Report on Assignment 4

Use of Statistics in Railway Engineering

W. M. Hager (chairman, subcommittee), H. T. Bradley, V. R. Copp, S. Danby, V. H. Doyle, B. Elkind, M. Friedman, C. C. Haire, L. W. Howard, B. H. Moore, J. K. Morrissey, C. F. Olson, W. C. Pauli, M. G. Pettis, A. T. Powell, H. L. Restall, E. J. Rockefeller, H. B. Sampson, J. E. Scharper, H. C. Wertenberger, J. L. Willcox.

Budgetary Procedures

Your committee submits this report as information.

Budgeting of expenditures in the engineering and maintenance of way departments of railways requires the application of broad engineering experience and engineering ingenuity to the development of the devices which will result in the successful consummation of the plan. Essentially, this requires that a broad experience in railway construction, maintenance, and accounting engineering be combined with a pre-eminent aptitude in the fields of cost engineering, production engineering and systems engineering. The application of these interdependent skills to the guidance of the productive effort may best be described as budget engineering.

The budget is a detailed plan of future operations and financial requirements drawn for the purpose of controlling the welfare of the business enterprise and securing for it the optimum profitable operation. The budget is a declaration of management's policies and should be regarded as management's main instrument for controlling and coordinating all efforts related to the expected trend of business.

General Considerations

The first requisite necessary to successful budget engineering is an announcement by management instituting the procedures and designating the officer responsible for carrying them out. Vested with this authority from management, the budget engineer will be in a position to call upon departmental heads for the estimates and reports which are necessary for the development and enforcement of the budget.

Development of the budget is dependent upon questions of policy to be decided by management. Therefore, the budget engineer should be in close liaison with management so he may carry out their decisions on policies relating to questions concerning the volume of product to be sold; the nature and amount of all services and operations required to produce the product; the production methods with respect to the required operations; capital expenditures; financial requirements; and finally, return on investment to reimburse lenders for the use of their money at a rate sufficient to attract new capital to the business.

The budget must be viewed therefore, as an instrument for coordinating these efforts, and, as such, it is the medium through which officers of the company will ultimately secure the formal authority for expending its funds. The estimates required for budgeting and upon which future appropriations will be based should be carefully prepared, concise yet precise—with an exact and true statement of the character and necessity for the expenditure and the benefits expected to be realized. It is equally important that the estimates of expenditures be correctly distributed to the real and nominal accounts, and that the time and amount of the cash requirements be indicated.

These are basic factors in the entire scheme of budgeting. Every action proposed that will affect income or finances must be considered as a subordinate constituent part of the entire plan. Every action must be contained within the scope and compass of

management's plan. It might be necessary to table proposals which would result in onerous charges to operating expenses or place a serious encumbrance on financial requirements. No elasticity should be permitted in supplying information for all of the basic factors. The measure of all of them must be given consideration by management. To omit any of them might result in approval of an action the management could ill afford to take, the payment of which might prove to be both difficult and embarrassing.

The budgeting system must be superimposed upon the existing procedures and accounting records. The estimates for the budget should, therefore, correspond closely to the accounting classification. The introduction of an elaborate system of forms, records and reporting media is merely wasteful paper shuffling and if carried to extremes contributes to the eventual collapse of the entire budgeting system.

In the following presentment it will be shown how these basic principles and a series of checks and balances for budgeting engineering and maintenance department operations may be imposed upon the existing routines and records with the minimum of additional effort. The same methods with minor variations may be used in the development of a complete budgeting system which will embrace all departments and every anticipated action.

Scheduling the Budget

Preparation of the budget must be started soon enough to permit its completion and adoption sufficiently in advance of the period it covers to permit proper planning and programming of operations by the officers who will be held responsible for its execution. Therefore, a timetable should be drawn setting a definite time for the completion of each step, beginning with the submission of departmental estimates.

Budget Estimates

Preparation of the budget begins with a call for departmental estimates. In the engineering and maintenance of way departments the estimates for maintenance, repairs, and physical changes in the plant should originate with the officer responsible for maintaining the economical productive capacity of the property. The estimates should be based upon actual needs. Thereafter, the estimates should be progressed through channels for study and approval by departmental heads. When the expediency of the recommendation has been firmly established with respect to operating requirements and cost, it is ready for submission to the budget engineer.

Basis of the Estimates

Basically the estimates must be expressed in terms of quantities and money. The engineering knowledge of the estimator is the principal fountain of information for the preparation of these forecasts. This knowledge is gained only from broad experience in the closest relationship to the problems and procedures associated with railway engineering, maintnance and accounting.

The existing accounting and statistical records, available standard costs, and the results achieved in earlier budget periods, will serve as important auxiliary tools in the hands of the experienced engineer. The use of these data, however, requires the exercise of great skill in their analysis and interpretation.

In the use of accounting and statistical records it is important that the user be thoroughly familiar with the accounting classifications and the regulations of the Interstate Commerce Commission relating thereto. He must understand the limitations which apply to the use of raw accounting results, and he must fully appreciate the necessity for supplementing these raw figures with other factual data.

In the use of cost standards it is essential that the distinction between the standard and the budget be understood. Budgets are forecasts of operations and costs, neither of which should be exceeded. Cost standards reflect typical costs which may be attained under desirable production methods. Both are instruments of control. If the production and unit costs are held within the limits of the budget, no investigation is necessary. On the other hand, any variance in cost with the standard should be investigated immediately. Costs in excess of the standard will require a correction in production methods. When costs are less than standard, a time and motion study is indicated as the basis for adjusting the standard. Therefore, comparison of costs with well established standards points the way to increased economies.

It is essential that the estimating engineer be fully cognizant of these differences. Both the budget and cost standards are forecasts of future expenses. While the use of standards will facilitate preparation of the budget, the engineer must remember that his estimate will be enforced against him and will be used as a measure of his efficiency. It is important, therefore, that he apply the cause and effect of changed operations to the adjustment of standards which do not fully reflect the advancement in technological enterprise. The ever forward development in engineering methods soon relegates standards to the realm of gray antiquity.

Uniform Estimates for Budget Recommendations

All budget recommendations and supporting estimates must be identical in style, uniformly incorporating all of the necessary basic factors. Consistency in this detail will be of assistance to management in the formulation of its opinions for final disposition of the recommendation. Uniformity will facilitate the systematic and orderly compilation of approved recommendations in the budget, and the final answer in all matters of financial importance to the management may be more easily ascertained.

There is attached as Form A* a suggested report form designed to accomplish these purposes.

Estimates and Controls Overall Expenditures

Form A will be recognized as resembling the form now generally used by railways in securing formal authority for expenditures involving additions and betterments. In its new arrangement it incorporates the features which will enable its adaptation to the service of a dual purpose in these instances.

The form is further designed to establish absolute controls over the performance and cost of maintenance work chargeable directly to operating expenses.

The authorities as now issued for additions and betterments are in reality job work orders for a specific performance. They receive the same treatment in the railway accounting routine as would be accorded the specific job order in a cost accounting system. The costs incurred are reported to the various authorities (job work orders) which are subsidiary ledgers of the general ledger.

It is obvious that this proven successful system for the partial control of expenditures may be tailored to create complete control with the minimum of alterations in the established procedures. The same method may be applied to control maintenance operations through issuance of a maintenance authority work order. A more simple solution of recording for cost control over maintenance expenditures might be found in the use of a classified subsidiary ledger wherein two columns are provided for each account so that job order numbers and costs may be posted respectively from left to right. Job

* All forms mentioned in this report are presented at end of report.

costs in each account would be summarized at closing before posting to the general ledger.

While the procedures advocated seemingly would cause insurmountable difficulties and a prodigious amount of increased effort, thoughtful reflection will show these beliefs to be unfounded. The procedures for chronologically recording job costs can easily be developed by the accounting officers. Thus, operations on direct maintenance which are now recorded in a conglomerate and commingled total will be recorded in a classified analytical manner.

Such complete control over all performances is a fundamental necessity in a budgeting system. Constant and immediate policing of estimates and costs are necessary to fix responsibility, avoid overruns, stop and correct inefficient operations, and prevent the performance of unauthorized work.

Using the Form Proposed for Budget Recommendations

The origination of budget recommendations, Form A, and its supplements, Form A–1 and A–2, will vary with the causes necessitating the proposed expenditure. Matters involving operating necessity (Class Code 5) might very well be initiated by the general manager. Recommendations involving expenditures for program items (Class Code 8) and ordinary maintenance (Class Code 9) should originate with the engineering officer directly responsible for the upkeep of the property and who is, therefore, most familiar with the needs and urgency of the various recommendations.

The originator is required to complete the budget recommendation in its entirety excepting only the spaces immediately at the top right and left sides, and at the bottom left side of Form A. The latter space will be filled in by management if the recommendation is adopted for inclusion in the budget. The spaces at the top of the form will be filled in when management issues the appropriate formal authority needed for commencement of the work. No work may be started before it has been formally authorized.

Thus, the form serves the purpose of a budget recommendation, an authority for expenditure, or as a maintenance authority work order. Its adaptation to these purposes to eliminate duplication of effort will be explained later in the narrative under this section. The similarity of Forms A and A–2 to the conventional authority for expenditure form is readily apparent. For this reason, the brief comments following are limited to the additional information which is needed exclusively for budget purposes.

1. Form A. Top center. Indicate by (x) the formal authority required to permit commencement of the work. An authority for expenditure is required in each instance where the work invoilves changes (increase or decrease) in the capital account. A maintenance authority work order is issued when all cost is chargeable directly to operating expenses.
2. Form A. Type of project indicated by (x).
   (a) Carryover and approved project. This type project has already been covered by a formal authority for expenditure but has not yet been completed. Carryover projects always involve changes in the capital account. It is the type of project for which funds must be made available and, therefore, is listed first in the order of project types. Also see explanatory item 5.
   (b) Program and general improvement. This category includes all recommendations under Class Codes 8, 9 and 10. The recommendation must be strictly limited to requirements for the current year. The formal authority (AFE or maintenance authority work order) ultimately issued to permit commencement of the work automatically expires at the end of the budget year.

(c) Consideration project. Recommendations in this category involve property changes which should be undertaken to improve the operations and reduce operating expenses. They are submitted for consideration of the management. They usually result in changes in the capital account and require an authority for expenditure to permit commencement of the work.

3. Form A. Priority. A separate set of operating division priority numbers shall be assigned to budget recommendations for program and consideration projects as described respectively in 2 (b) and 2 (c) above. This numbering establishes the order of importance for each recommendation, and serves to guide management in its deliberations with respect to the final disposition of each recommendation.

4. Form A–1. Estimated approximate monthly expenditures. This section of the recommendation is the foundation for the entire budget. It is a prediction of the time and amount of the financial requirements and is the basis for determining the availability of funds. It is essential, therefore, that the time, character and amount of the expenditures be estimated with reasonable accuracy on the assumption that the full amount of the expenditure required will be authorized. In the lower half of Form A–1 the time and amount of expenditures chargeable to operating expenses is shown by primary accounts.

5. Form A–1. Budget recommendations for carryover and approved projects require only Forms A and A–1. A reproduction of the original Form A may be used. Form A–1 must be prepared to cover expenditures in the current year, and must show actual prior year's charges and estimated future expenditures as provided for on Form A–1.

The budget recommendation should be passed through channels for examination and approval by each higher ranking officer. A meeting at the district level with the general manager, the chief engineer maintenance of way and their staffs should be arranged for the purpose of reviewing the budget recommendations. Budget recommendations approved by these officers are then forwarded to the chief engineer for his examination and review. Thus, the recommendations pass through the hands of all officers who are familiar with the operating needs and maintenance requirements of the property. The budget recommendations which are approved by the chief engineer will then be forwarded to the budget engineer.

The budget engineer will then assemble the requests and prepare a tentative budget. A meeting should follow at the top level with the operating vice president, general managers, chief engineer, the district chief engineers maintenance of way, and the budget engineer for a final review of the budget recommendations.

Recommendations surviving this final screening would be approved by the operating vice president for inclusion in the budget. At this time the recommendation would receive its budget number to be inserted in the space provided at the bottom left side of the form.

Recommendations that should be undertaken in the early part of the budget year would at the same time be approved for the issuance of the appropriate formal authority. The required number of copies under the existing routine, reproduced from the original budget recommendation, would be immediately forwarded to the proper accounting officer for check of accounting and assignment of the AFE or maintenance authority work order, thus establishing the initial control over future expenditures. Copies of the fully completed recommendation, with budget and formal authority numbers, would be fur-

nished to all interested parties as under the existing procedure followed in the distribution of conventional authority for expenditure forms.

Where recommendations are approved only for inclusion in the budget, all interested parties should receive a reproduction of the original Form A budget recommendation showing the budget numbers. It is not necessary to reproduce Forms A–1 and A–2. The original Forms A, A–1, A–2, for all recommendations where approval is limited to inclusion in the budget, will be retained by the chief engineer. At the appropriate time subordinate officers will request the chief engineer to secure the necessary formal authority permitting commencement of the work. To set this in motion the chief engineer need merely be notified of the budget number for which formal authority is required. The original budget recommendation on file with the chief engineer would then be processed as noted in the preceding paragraph.

As this method contemplates extensive use of the original budget request, a good quality paper should be used to withstand continued handling and the wear caused by the reproduction processes.

Department and Class Codes, Form B

The departmental and class codes as shown on Form B are merely illustrative of a procedure suggested to facilitate identification of the departments and the types of work to be performed. The codes are susceptible of a broader or narrower application as may be considered necessary to meet the needs of an individual carrier.

A coding system is essential for the systematic and orderly compilation of the budget by departmental subdivisions and classes, leading to consolidated departmental and system totals.

Class Codes 1 to 7 incl. would apply to all departments. Class Codes 8 and 9 as presented apply only to the maintenance of way department. It may be found desirable to establish Class 8 subcodes for program work in other departments.

The subcodes for Class 8 were adopted to meet the ever growing trend toward mechanization of maintenance operations. Thus, Class Code 8 provides subcodes for completely mechanized track and bridge and building gangs, manned by personnel trained in the orderly sequence of work operations and in the use of the machines and power tools needed to equip the gang for a specific repetitive operation.

Separate budget requests must be prepared for each project under Class Code 8. This is necessary to permit proper programming of mechanized gangs. The estimate must include all costs of labor, material and supplies. Well established standards which are possible of achievement will simplify the estimating when work is performed by mechanized gangs.

Track and bridge and building gangs are included in Class Code 9. The following is required in the Class 9 budget recommendation.

201.00 Superintendence. Pay and expenses of supervisory employees. To be prepared to show the number of employees of each class on the division by headquarters locations.

271.00 and balance of the numbered accounts. The estimates for these codes may be based upon past experience. It would be reasonable to assume that the cost in these accounts (except Class 9–272) would vary directly with the use of labor.

Bridge and Building gangs. Separate estimates are required for each class code. Each estimate should show the number of employees of each labor classification on the division by headquarters location. A reasonable estimate of

the materials and supplies to be consumed shall also be included. Labor and material should be distributed to the proper primary accounts. Where the account classification is not readily determinable, as in the case of the bridge and building gangs, the total estimated cost should be distributed by primary accounts on an estimated basis.

These estimates should show, separately, the detailed cost of work chargeable to other general operating expense accounts. An example is the cost of cleaning freight cars chargeable to Account 402, train supplies and expenses.

The budget recommendation for roadway shops, rail cropping yards and timber treating plants, Class Code 8–220, should be prepared to show the anticipated production. The estimate for cost of operation should be in detail, showing the number of employees of each labor classification and the materials and supplies to be consumed. The same detailed estimates are required for roadway shops handling repairs to roadway machines.

Some carriers may wish to include an estimated value to provide for the absorption of operating expenses of an extraordinary nature. This is a matter of individual choice, but since such extraordinary expenses are unpredictable, it would seem more prudent to provide for them through adjustments to be explained later in the text.

Preparing the Annual Budget

Because it was not clearly pointed out in the earlier part of the text, it is now mentioned that the budget engineer is also to retain copies of all budget recommendations. The approved recommendations will be the source of his data for preparation of the consolidated annual system budget showing the allocation of funds to the departments, by divisions and classes of work.

First in the order for compilation for each department would be the carryover and approved projects, followed by program items and consideration projects. Each of these categories is to be compiled separately. Form C–1 illustrates a method that might be used to assemble the approved budget recommendations for carryover items, permitting a summary by divisions, classes of work and character of expenditure.

The location and description column should give as brief a description as is necessary for identification. The parenthetical notation as shown in this column is the budget number for the preceding year, the letter indicating the departmental code designation. The class of work and budget number are indicated respectively by the numerals.

As was noted in the comments under department and class codes, separate recommendations are required to be submitted for all Class Code 8 projects. To illustrate, it is not desirable to include all cycle timbering, ballasting and surfacing of track (Class Code 8–220.04) for an operating division on one recommendation. To do so creates complications in effectively programming the work and makes intelligent retrenchment more difficult in the event of a disaster.

The same arrangement suggested on Form C–1 may be used for the compilation of program and consideration projects. Some carriers may wish to show more complete information regarding the necessity for consideration projects. It would be particularly desirable to earmark the importance of recommendations originating with the management.

A departmental summary by class codes should then be prepared from the summaries of the three principal categories to show the following:

BUDGET FOR THE YEAR 19....

Dept. B—Maintenance of Way—Roadway and Track

Class	Carryover and Approved		Program and General Improvement		Consideration		Total	
	A.& B.	O.E.	A.& B.	O.E.	A.& B.	O.E.	A.& B.	O.E.
1	X	X	X	X	X	X	X	X
thru								
10	X	X	X	X	X	X	X	X
Total	$1,572,000 *	$228,000 *	X	X	X	X	X	X

*Totals from Form C-1.

It will be seen that the final departmental summaries as above illustrated are easily combined into a system total by departments and class codes. The complete budget, suitably bound and properly indexed, should be distributed to all departmental heads charged with the responsibility for carrying out the decisions reached by management.

Fixed Budgets and Flexible Budgets

To accomplish the purpose of budgeting, the budget engineer must be continually alert to changed conditions.

Constant review of the established standards and comparison of performances may indicate the need for new and more efficient production methods which would substantially reduce unit costs. This, in turn, might warrant an immediate capital expenditure to bring about the potential increased economy. Management might order the adoption of new and more progressive policies or may by circumstance be compelled to rescind or otherwise revise an action or authority previously approved. Such important changes would be accomplished by the issuance of a supplement to the budget.

The annual budget and its supplements may be likened to an assembly drawing, while a monthly budget serves as a detailed working drawing. The monthly budget introduces flexibility which is essential to adapting the annual budget to suddenly changed conditions. The estimating of income is not an exact science, and estimators are unable to prophesy acts of God which might wreak havoc on the property. These are but two factors that might necessitate adjustments in the allotment of available funds. Such temporary retrenchment may be accomplished in the allotments made available through the monthly budget.

Thus, the budget supplements and the monthly budgets are important tools placed in the hands of the budget engineer to aid him in carrying out the managements declared policy.

Supplements to the Annual Budget

Form C–2 illustrates a method that might be used by the budget engineer in amending the annual budget. It shows corrections in the amounts to be budgeted under carryover and approved projects for Department B in the first month following adoption of the annual budget. The total originally budgeted (taken from Form C–1) are entered first. Changes authorized are grouped by classes of work and the revised budget total at the end of the period is given. This revised total would be entered first in the next supplement to the budget.

A revised summary by classes of work is given to facilitate preparation of the amended system budget by departments and class codes.

The reconciliation under the column provided for changes is desirable. A review of the statement shows the funds for two projects, (B) which required additional allotments, were made available from projects (A), where it has developed that the full amount originally authorized would not be used in the current year.

Item (C), a project previously included in the budget with consideration projects, was ordered started and the necessary formal authority issued. The same item will be removed in the supplement for consideration projects.

Item (D) provides an additional allotment for an immediate expenditure brought about by a disaster.

The departmental summaries by principal categories lead to consolidated amended departmental totals, and the consolidated departmental totals lead to consolidated amended system totals. The following abbreviated pro-forma form depicts a method that might be used to develop amended system totals.

ANNUAL BUDGET 19...

First Supplement As Amended to (Date) ..... Summary by Departments

Dept.	Carryover and Approved		Program		Consideration		System total Amended to (Date)		
	A.& B.	O.E.	A.& B.	O.E.	A.& B.	O.E.	A.& B.	O.E.	Total
A Balance Jan. 1, 19____	X	X	X	X	X	X	X	X	X
Changes 1st Supplement_____	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X

All departments to be shown in similar manner to produce grand totals by categories for the system.

SUMMARY BY CLASSES

Class	Balance (Date)	Additional Allotment	Changes	System total Amended to (Date)
1_____	X	X	X	X

All classes to be shown in similar manner to produce system totals.

The circulation of each complete budget supplement should be in accordance with the distribution of the original budget.

Monthly Budgets

Form C–3 illustrates a method that might be used by the budget engineer for the dual purpose of authorizing monthly allotments and controlling gross expenditures for each project undertaken during the year.

It is well to reiterate that no work, whatever its nature, may be commenced until the necessary formal authority has been issued. To do so would complicate operation of the budget and its controls and would ultimately defeat the very purpose of a budget system. In cases of emergency, management can quickly issue the necessary formal authority under the procedures advocated. Allotments therefor are made only for authorized projects.

The combined monthly allotment and control sheet is a continuing and expansible record. As a project is authorized it will be added in the succeeding issue and will continue to be shown in following monthly budgets even though the project may be 100

percent complete. Thus, a continuing control is maintained over each project, finally showing a comparison of the actual cost during the year with the estimated cost on which budget requirements were based.

The preparation of monthly budgets requires that the budget engineer work in close cooperation with departmental heads. Whenever the annual budget is amended (through budget supplements), or whenever it becomes necessary to shift allotments in the monthly budget from one project to another or as between the real and nominal accounts, departmental heads should be given the opportunity to pass upon the proposed revision of monthly apportionments. It is preferred that revised Forms A–1 be prepared to avoid confusion in the determination of funds needed to meet future operating and financial requirements.

Since the monthly budget form relates to the appropriation of funds and the control of expenditures, the percentage of each project completed should be related to the estimated cost in the ratio each item of work bears to the total estimated cost.

The monthly budget and control sheet should be furnished to all departmental heads who receive copies of the annual budget and its supplements.

Controlling Expenditures

The information for Col. 6, Form C–3, should be furnished the budget engineer by the accounting department at the earliest date possible following the last monthly closing of charges. Such a statement should show the charges recorded in the last month and the total to date, both separated as between charges to the capital account and operating expenses for each project, properly identified by its authority and budget numbers.

Under the normal accounting routine these figures generally are not available until about the middle of the month following performance of the work. The budget engineer will already be engaged in preparing the next monthly budget and control sheet. The statement of cost incurred at the latest closing of the accounts might not include all the charges incurred during the previous month.

This requires close cooperation between the budget engineer, the accounting department and other departmental heads in developing the figures for Col. 6 with the greatest degree of accuracy. Care must be exercised with respect to delayed charges, such as payments for contract work, material charges, etc., approved for payment too late to be included in the disbursements for the proper accounting period. Such delayed items require consideration also in the changed demand upon the funds of the company unless the funds are properly reserved when the monthly budgets are adopted.

The omission of consequential items would, of course, be detected by the budget engineer in the differences to be entered in Col. 10 of Form C–3, but it would seem that more effective and more efficient controls might be established through the creation of an earned surplus reserve. Cash requirement would then need to be defined to fit the accounting practice of individual carriers. Some carriers might not care to consider payrolls and material from stock as cash reserve items. As an illustration to show the possibilities, the entry creating the reserve might be:

Dr.	Earned Surplus Unappropriated	XXX	
Cr.	Earned Surplus Appropriated—Cash requirement budget for (month and year)		XXX

If it is desired to create a covered reserve, a compound entry would be issued to maintain separate identities of the cash funds. As payments are vouchered, the entries would be reversed. The balances remaining at the end of each period can be reconciled

to determine delayed items to be added to the last statement of recorded cost. The amounts for such delayed charges would not be cleared from the monthly reserve until they were actually paid. Balances remaining because payments were less than had been anticipated when the reserve was set up would be reversed and restored to earned surplus. This reversal entry would be considered in reworking the schedule for future allotments and cash requirements.

Col. 5 on Form C–3, as illustrated, shows the budget allotment for the previous month. Since the monthly budget must be prepared in advance, it represents the costs that would be incurred in the current month. Such actual costs would not be available until the fifteenth of the following month. Budget allotments, therefore, were used as it was felt all officers responsible for enforcing the budget would realize the necessity for a strict adherence to the plan. Because of this the variance in actual expenditures should be rather inconsequential and would be revealed when the actual cost for that month is included in the accounting department's statement. Compliance with demands of the management as set forth in the budget is simply a matter of education. When subordinate officers realize that the purse strings will be drawn tight within a short time following a period of extravagance, the resulting consequences will cause them to adopt a more watchful attitude over their responsibility for the company's financial welfare.

Some carriers have developed a system of field reporting to produce cost figures in the current month. We quote excerpts from the information furnished this committee regarding this feature so the reader may formulate his own opinion as to the method of control most suitable to his needs.

1. "Each department assembles its own reports of estimated expenses incurred for each weekly period. This information is furnished us four days after the close of the weekly period . . .".
2. "During the months, the chief engineer's office maintains close contact with the divisions approximately once a week to determine whether expenses are running within the allowance".
3. "We usually produce a preliminary estimate of net revenue along about the fifth of the month and there is a sufficient degree of accuracy to this figure that it comes very close to the final closing".
4. "Weekly reports are submitted to the engineer maintenance of way by each division indicating the amount expended during the seven-day period reported . . . before the fourth day of the subsequent month each division forwards to the engineer maintenance an estimated actual expenditure for the previous month . . .".
5. "Procedures have been prescribed specifying that division engineers will be required to set up daily from the daily reports received, the amounts chargeable to operating expenses, including the number of men, the estimated cost of labor, straight time and overtime, the cost of materials and work train expenses. He will accumulate these expenses separately for the 1st to 7th, 14th, 21st and last day of each month and report the totals for each period to the district engineer. Each district engineer will prepare consolidated reports for each period . . .".

The reader is referred also to a previous report of this committee regarding the control of expenditures, as published in the Proceedings, Vol. 54, 1953, pp. 867–870.

The development of controls needed to supply the information for Cols. 5 and 6 on Form C–3 is a matter to be explored and developed in cooperation with the accounting

officers. Special field reports should be held to the minimum so field supervisory officers may devote their full time to supervision rather than to the compilation of cost data which should be produced in the regular accounting routine.

Overruns and Underruns

The differences between budgeted and actual expenditures in Col. 10 on Form C–3 must be explained when they exceed a reasonably allowable difference. The marginal profit realized in the railway industry demands that the permissable tolerance be held to the minimum. It was earlier said that the budget is a forecast of operations and cost, neither of which should be exceeded. Therefore, when budget requests are based upon actual needs, reliable cost data and standards which are possible of achievement, it is not unreasonable to assume that the variances in actual costs should be inconsequential. The degree of variance will depend upon the exactitude of the cost standards and other estimating media used; therefore, the permissable allowable difference will vary with individual carriers.

When overruns are explained to the satisfaction of the management, they should be authorized by supplementary Form A–1 as additional budget allotments. Otherwise the budget engineer will be compelled to make adjustments in other allotments if the overrun is not already offset.

Underruns should be investigated to police standards and prevent padding for the misappropriation of funds.

Programming, and Equalization of Operating Expenses

Roadway machines developed in recent years make it possible to bring assembly line and mass production techniques to the field in railroad maintenance. Mass production techniques require careful and effective planning so the optimum output may be realized through maximum utilization of the machines.

Equalization of all operating expenses is an important aid in effective programming. With the equalization of expenses, schedules could be arranged to fit climatic conditions, thus permitting a greater utilization of the machines. The schedule may further be arranged to fit periods of light traffic density on trunk lines to secure the most favorable unit costs. These are but some of the considerations required in effective programming. Such effective programming, combined with equalization, will tend to reduce the investment in machines, will stabilize employment and will elminate excessive labor turnover.

The equalization of all expenses in conjunction with the adoption of a budgeting system deserves serious consideration. All of the data necessary for these purposes is required to be furnished in the system outlined. Whether the equalization be based on estimated operating expenses or estimated income is a matter that is optional with individual carriers. Equalization based on income (see Accounting Bulletin No. 15, "A" Case Accounting Interpretations, issued by the Bureau of Accounts, Cost Finding & Valuation, Interstate Commerce Commission, Case A–162) has the desirable effect of equalizing net railway operating income.

Conclusion

Your committee believes this paper presents the essential considerations necessary for the development of a successful budgeting system. They were developed from an intensive study of the methods successfully used by several carriers. The procedures advocated should produce a composite system of budgeting which embraces the better practices found in each of the methods studied.

(Text continued on page 620)

Form A

NORTH & SOUTH RAILROAD

BUDGET RECOMMENDATION 19__

Maintenance Authority
Work Order No. _____
Date Approved _____
Budget No. _____

Requires:
☐ Authority for Expenditure
☐ Maintenance Authority

A.F.E. _____
Date AFE Approved ____
Budget No. _____

☐ Carryover & Approved Project
Budget No. _____ Year ____
☐ Program & General Improvement
☐ Consideration Project

Division _____
Department _____
Class _____
Priority _____

Location of Project: State _____ Val. Sec. ____ Station or M.P. _____

Description of the project and necessity for the work:

(Give a brief, adequate description of the project. Attach sketch or plan. If any operating economies are to be effected, explain and state what the annual savings will be.)

SUMMARY

Estimated			Actual	
Gross Capital Cost	$70,000		.....	
Property Retired	4,000 Cr.		.....	
Net Capital		$66,000		.....
Incidental Operating Expense	$13,600		.....	
Service Loss on retirements	2,000		.....	
Total Operating Expense		15,600		.....
Accrued Depreciation		500		.....
Salvage		1,500		.....
Other Accounts:				
I.& C.		1,400		.....
.....		.....		.....
.....		.....		.....
.....		.....		
.....		.....		.....
Gross Cost		$85,000		

Recommended for Budgeting: Date.....
..... Title .....
..... Title .....

Approved: Date .....
..... Title .....

Budget No. .....
Maintenance Authority
Work Order .....

A.F.E. Recommended: Date .....
..... Title .....
..... Title .....

Approved: Date .....
..... Title .....

NORTH & SOUTH RAILROAD Form A-1

Budget Recommendation 19__

Division _____
Department _____
Class _____
Priority _____

Location and description of project: .....
.....
.....

Estimated Approximate Monthly Expenditures Current Year

Month	Gross	Net Capital	Operating Expenses	Other Accounts	Cash Outlay
1					
2					
3					
4	3,100	4,000 Cr.	5,100	2,000	
5	12,000	10,000	2,000		
6	23,500	20,000	3,500		
7	25,000	20,000	5,000		
8	15,000	15,000			
9	6,400	5,000		1,400	
10					
11					
12					
Total for current year	85,000	66,000	15,600	3,400	
On Carryover Projects show:					
Expended in prior years	X	X	X	X	
Estimated carryover future years	X	X	X	X	
Estimated Total Cost	X	X	X	X	

Estimated Approximate Monthly Expenditures Current Year
Operating Expenses & Other Accounts.

Month	Total	Acct. 201	Acct. 208	Acct. 220	Acct. 249	Acct. 267	Acct. 270	Acct. ____	Acct. 702½C	Salvage	I.&C.
1											
2											
3											
4	7,100	100			2,000	2,000	1,000		500	1,500	
5	2,000			2,000							
6	3,500		3,500								
7	5,000		3,500	1,500							
8											
9	1,400										1,400
10											
11											
12											
	19,000	100	7,000	3,500	2,000	2,000	1,000	____	500	1,500	1,400

NORTH & SOUTH RAILROAD Form A-2

BUDGET RECOMMENDATION 19__

Division _____
Department _____
Class _____
Priority _____
Sheet _____ of _____

Office of ..... Date .....

Location and description of Project: .....
.....
.....
.....

DETAILED ESTIMATE

.....

Estimated by ..... Title ..... Estimate approved: by ..... Title .....

NORTH & SOUTH RAILROAD

FORM B

DEPARTMENTAL AND CLASS CODES TO BE USED IN BUDGET RECOMMENDATIONS

Departmental Code

A—Engineering and/or Construction Department
B—Maintenance of Way—Roadway and Track
C—Maintenance of Way—Bridges and Buildings
D—Maintenance of Way—Water Service
E—Communications
F—Signal
G—Roadway shops
H—Rail cropping yards
I—Timber treating plants

Class Code

1—Safety
2—Law
3—Labor
4—Contract liability
5—Operating necessity
6—Traffic
7—Savings
*8—Program items and general improvements
9—Ordinary maintenance
10—Unassigned items

* See schedule of subclassifications.

SCHEDULE OF SUBCLASSIFICATIONS

Note: 1. Decimal designations .01 to .10 are reserved in each subclassification for items of work peculiar to each primary account. Thus in Account 202, Class 8, the complete class code for weed control would be 8–202.01.

2. Decimal designations .11 to .22 covering work by crafts, as follows, will apply to all accounts.

.11 Masonry
.12 Waterproofing
.13 Structural steel
.14 Carpentry
.15 Sheet metal and roofing
.16 Plastering
.17 Painting
.18 Heating
.19 Plumbing
.20 Electrical
.21 Mechanical
.22 Air conditioning and ventilating

SCHEDULE OF SUBCLASSIFICATIONS (CONT'D)

Code 8—Program Items and General Improvements.

202—Roadway Maintenance
- 202.01 Weed control
- 202.02 Ditching
- 202.03 Banking
- 202.04 Stabilizing roadbed—grouting
- 202.05 Stabilizing roadbed—post driving
- 202.06–202.10 See Note 1
- 202.11–202.22 See Note 2

206—Tunnels and Subways
- 206.01 Scaling tunnels
- 206.02–206.10 See Note 1
- 206.11–206.22 See Note 2

208—Bridges, Trestles and Culverts

210—Elevated Structures
- .01–.10 Reserved in each account. See Note 1.
- .11–.22 For each account as per Note 2.

220—Track Accounts
- 220.01 New rail program
- 220.02 Relay rail program
- 220.03 Timbering, ballasting, surfacing and dressing track following rail laying
- 220.04 Cycle timbering, ballasting and surfacing of track
- 220.05 General smoothing, ballasting and surfacing
- 220.06 Roadway shops
- 220.07 Rail cropping yards
- 220.08 Timber treating plants

221—Fences, Snowsheds and Signs

227—Station and Office Buildings

229—Roadway Buildings

231—Water Stations

233—Fuel Stations

235—Shops and Enginehouses

237—Grain Elevators

239—Storage Warehouses

241—Wharves and Docks

243—Coal and Ore Wharves

Same subclasses in each of the foregoing as indicated in Notes 1 and 2.

SCHEDULE OF SUBCLASSIFICATIONS (CONT'D)

247—Communication Systems

249—Signals and Interlockers
- .01 Poles and fixtures
- .02 Aerial wire and cable
- .03 Underground cable and conduit
- .04–.10 See Note 1
- .11–.22 See Note 2

253—Power Plants
Same subclasses as indicated Notes 1 and 2

257—Power Transmission Systems
Same subclasses as indicated under classes 247 and 249

265—Miscellaneous Structures
Same subclasses as indicated Notes 1 and 2

269—Roadway Machines
- 269.01 Additional purchases
- 269.02 Replacement purchases
- 269.03 Repairs to roadway machines

273—Public Improvements, Maintenance
Same subclasses as indicated Notes 1 and 2

Code 9—Ordinary Maintenance
- 201.00 Superintendence
- 271.00 Small tools and supplies
- 272.00 Removing snow, ice and sand
- 274.00 Injuries to persons
- 275.00 Insurance
- 276.00 Stationery and printing
- 277.00 Other expenses
- 281.00 Right of way expenses
- B. & B. Bridge and Building Forces
- Track Track Forces
- Water Water Service Forces
- Comm. Communication Forces
- Signal Signal Forces

Code 10—Unassigned Items
- 266.00 Road property depreciation
- 278.00 Maintaining joint facilities—Dr.
- 279.00 Maintaining joint facilities—Cr.

NORTH & SOUTH RAILROAD — Form C-1

Budget for the Year 19__
Dept. B - Maintenance of Way - Roadway & Track
Carryover & Approved Items

Operating Division	Class Code	Budget No.	Authority for Expenditure	Location and Description	A.& B.	O.E.	Total
North	1	1-1	100,000	M.P. 10.0 Bridge (19 - B-1-1)	100,000	10,000	110,000
		1-2	100,101	M.P. 50.0 " (19 - B-1-6)	50,000	5,000	55,000
	1	Total			150,000	15,000	165,000
	2	2-3	100,102	(19 - B-2-10)	10,000	1,000	11,000
	3	3-4	100,103	(19 - B-3-25)	22,000		22,000
	4	4-5	100,104	(19 - B-4-30)	2,000		2,000
	5	5-6	100,105	(19 - B-5-35)	200,000	50,000	250,000
		5-7	100,106	(19 - B-5-40)	60,000	10,000	70,000
	5	Total			260,000	60,000	320,000
	6	6-8	100,107	(19 - B-5-45)	50,000		50,000
	7	7-9	100,108	(19 - B-5-50)	30,000		30,000
North	Total Division A				524,000	76,000	600,000
Middle	Total Division B) For illustration, assumed to be the				524,000	76,000	600,000
South	Total Division C) same classes and amounts as above				524,000	76,000	600,000
System Totals - Carryovers & Approved Items					1,572,000	228,000	1,800,000

Summary by Classes and Divisions

Class	Division A A.& B.	Division A O.E.	Division B A.& B.	Division B O.E.	Division C A.& B.	Division C O.E.	System A.& B.	System O.E.	System Total
1	150,000	15,000	150,000	15,000	150,000	15,000	450,000	45,000	495,000
2	10,000	1,000	10,000	1,000	10,000	1,000	30,000	3,000	33,000
3	22,000		22,000		22,000		66,000		66,000
4	2,000		2,000		2,000		6,000		6,000
5	260,000	60,000	260,000	60,000	260,000	60,000	780,000	180,000	960,000
6	50,000		50,000		50,000		150,000		150,000
7	30,000		30,000		30,000		90,000		90,000
	524,000	76,000	524,000	76,000	524,000	76,000	1,572,000	228,000	1,800,000

NORTH & SOUTH RAILROAD
ANNUAL BUDGET 19__
First Supplement
Items added or deducted January 1, 19__ to January 31, 19__
Dept. B - Maintenance of Way - Roadway & Track

Form C-2

Class	Budget Number	Authority	Location and Description	Originally Budgeted	Budget for 19 A.& B.	O.E.		Total
			CARRYOVER & APPROVED ITEMS					
Total as of January 1, 19__			(From Form C-1)		1,572,000	228,000		1,800,000
1	B-1-1	100101	M.P. 50 Bridge (Deferred)	110,000	(50,000)	(5,000)	(A)	(55,000)
	B 1-200	100200	M.P. 100	-	40,000	5,000	(B)	45,000
	B 1-201	100300	M.P. 110	-	8,000	1,000	(B)	9,000
1	Total Change				(2,000)	1,000		(1,000)
5	B 5-50	100000	Strengthen bridges	250,000	200,000	50,000	(C)	250,000
	B 5-12	100122	(Deferred)	130,000	(20,000)	(45,000)	(A)	(65,000)
	B 5-250	100150	Replace bridge destroyed	-	150,000	50,000	(D)	200,000
5	Total Change				330,000	55,000		385,000
Total change all classes					328,000	56,000		384,000
Total Carryover and Approved Items revised to January 31, 19__					1,900,000	284,000		2,184,000

Revised Summary

Class	Budgeted as of Jan. 1, 195 A.& B.	O.E.	Total	Changes Jan. 1 to Jan. 30, 195 A.& B.	O.E.	Total	Total Revised to Jan. 31, 195 A.& B.	O.E.	Total
1	450,000	45,000	495,000	(2,000)	1,000	(1,000)	448,000	46,000	494,000
2	30,000	3,000	33,000				30,000	3,000	33,000
3	66,000		66,000				66,000		66,000
4	6,000		6,000				6,000		6,000
5	780,000	180,000	960,000	330,000	55,000	385,000	1,110,000	235,000	1,345,000
6	150,000		150,000				150,000		150,000
7	90,000		90,000				90,000		90,000
	1,572,000	228,000	1,800,000	328,000	56,000	384,000	1,900,000	284,000	2,184,000
Reduction in allotment (A)				(70,000)	(50,000)	(120,000)			
Portion of (A) reallocated (B)				48,000	6,000	54,000			
Consideration project authorized (C)				200,000	50,000	250,000			
Additional allotment authorized (D)				150,000	50,000	200,000			
				328,000	56,000	384,000			

Form C-3

NORTH & SOUTH RAILROAD
Budget for (Month)

Dept. B - Maintenance of Way - Roadway & Track.

(1)	(2)	(3)	(4)		(5)		(6)		(7)		(8)			(9)			(10)	
Op'g. Div.	Budget: Number	A.F.E.	Allotment for (Current Month): A.& B.	O.E.	Allotment for (Previous Month): A.& B.	O.E.	Actual Expenditures to (Date Available): A.& B.	O.E.	Future Allotments this year: A.& B.	O.E.	Total Estimated or Actual Expenditures: A.& B.	O.E.	Total	Total Allotment in Annual Budget: A.& B.	O.E.	Total	Difference: Over + Under -	% Complete 1/1/—
									CARRYOVER & APPROVED ITEMS									
														100,000	10,000	110,000		
														*S1 (50,000)	(5,000)	(55,000)		
North:														50,000	5,000	55,000	-	
	B1-1	100100	4,100	-	-	5,000	-	-	45,900	-	50,000	5,000	55,000	50,000	5,000	55,000	-	
	B1-2	100100	1,000	3,000	-	-	-	-	49,000	2,000	50,000	5,000	55,000	50,000	5,000	55,000	-	
	Class 1 Total		5,100	3,000	-	5,000	-	-	94,900	2,000	100,000	10,000	110,000	100,000	10,000	110,000		
	B2-3	100102	-	-	-	-	9,500	1,000	-	-	9,500	1,000	10,500	10,000	1,000	11,000	-500	100
														40,000	90,000	130,000		
														*S1 (20,000)	(45,000)	(65,000)		
														20,000	45,000	65,000	+500	
	B5-12	100122	-	10,000	-	15,000	-	5,500	20,000	15,000	20,000	45,500	65,500	*S1 150,000	50,000	200,000		
	B5-250	100150	50,000	25,000	-	-	2,000	10,000	98,000	15,000	150,000	50,000	200,000	170,000	95,000	265,000	+500	
	Class 5 Total		50,000	35,000	-	15,000	2,000	15,500	118,000	30,000	170,000	95,500	265,500	170,000	95,000	265,000		
North:	Grand Total		55,100	38,000	-	20,000	11,500	16,500	212,900	32,000	279,500	106,500	386,000	280,000	106,000	386,000	-	-
														-500	+500	-		

* Corrections as provided for in the first supplement to the annual budget (See Form C-2).

While this committee has issued earlier reports on this subject, it was felt that a more comprehensive treatise on the subject would be timely and in keeping with the trend toward mass production methods. The benefits to be realized from the combined use of a budget and cost controls, both based upon reliable cost standards, is a matter this committee has many times brought to the attention of this Association. The earlier reports of your committee will be found to be as vital today as when first published. They contain much valuable information that will stimulate the imagination of the reader and spawn ideas that might produce desired refinements needed to fit problems peculiar to particular cases.

Report on Assignment 5

Construction Reports and Property Records

W. S. Gates, Jr. (chairman, subcommittee), R. B. Aldridge, F. B. Baldwin, V. R. Copp, V. H. Doyle, B. Elkind, B. Firestone, M. Friedman, R D. Igou, W. A. Krauska, C. E. Lex, Jr., C. B. Martin, B. F. Nauert, F. H. Neely, J. H. O'Brien, L. A. Pelton, D. E. Pergrin, W. F. Sanders, H. A. Shinkle, J. N. Smeaton, J. L. Wilcox, L. Wolf.

Use of Tabulating Machines in Engineering Department Procedures

Preparation of Returns to the Interstate Commerce Commission, Bureau of Accounts, Cost Finding and Valuation, Covering Annual Report of Property Changes—BV 588

General

Each railroad is required to file yearly with the Interstate Commerce Commission, Bureau of Accounts, Cost Finding and Valuation, a report of additions to and retirements from their investment in land, physical property and equipment. The forms to be used, method of reporting and regulations governing the reporting, are found in the Supplements to the Bureau's Valuation Order No. 3.

The usual procedure is for the carrier to assemble all the facts pertaining to the construction units placed, and their related costs, and to transcribe a pencil completion report, following the applicable rules and regulations. The pencil reports are typed, separated into groups by classes of projects and valuation sections, and through the medium of pencil collection sheets of one kind or another the common items are brought together so the pencil copy of the BV 588 may be prepared. Summaries of the individual valuation sections are combined into state and system summaries, which are balanced against the related charges in the books of account with differences being explained on reconciliation statements. The pencil BV 588's are typed and filed with the Bureau.

The purpose of Committee 11's study was to determine if the inherent advantages of modern punched card equipment might not be utilized to perform the very considerable task of assembling, totalizing and typing of the BV 588 reports.

Punched Card Procedure-Starting Point

After a careful study of existing procedures used by the various railroads, it was found there was a point at which all procedures came to a common ground. This point was the pencil completion report (the completion report being one of the requirements of the Bureau's Valuation Order 3 regulations) which, besides being a comparable point

for all carriers, is also the first time the units and their related costs are stated in the form required on the BV 588 reports. Therefore, the problem resolved itself into a study to demonstrate that if one were to transcribe (punch) data shown on the pencil completion report into a set of punched cards would he be able to perform the remaining steps with the tabulating machine equipment. The tests made, using a printing tabulating machine with its related equipment, demonstrated that the equipment had both the capacity and the selective flexibility to produce the desired results, once it is furnished with the information available on the pencil completion report.

During the course of the study, extending as it did over a period of several years, extensive design changes in punched card equipment have made the pencil completion report, as a point of beginning, a most advantageous one. By use of the modern electric typewriter-key punch combination, the punch card becomes a by-product of a typing operation and the normal operation of typing a pencil report will, with no expenditure of additional labor, produce both a typed report and a set of punched cards for use in the subsequent steps of the procedure, ending at a machine produced BV 588 report.

The Punched Card

An eighty-column tabulating card (Exhibit A*) provides space for punching the following information:

1. Valuation Section
2. Completion Report—Year and number
3. Location of Project—Mile, kind and number
4. Ownership Code—i.e.: Jointly owned, Joint participation, donations, etc.
5. Description of Item (See Note)
6. Basic Valuation Identification
7. Primary Account
8. Construction Unit
9. Number of Units—Added or retired
10. Accounting Cost—Added or retired
11. Restated Valuation Cost (Where required)

Note: Descriptions require uniform standard brief description set up in Standard Practices.

The design of the card is such that coding is required only for Item 4, the balance of the information being transcribed directly from the pencil completion report. The card is divided into alphabetical and numerical fields, the first being used to describe or identify the item, and the latter to record number of units, costs and the like. Each card will, after being punched, be interpreted, or with one type of card punching equipment be interpreted as it is being punched. This interpreting prints across the top of the card the information that has been punched. Thus, it is unnecessary to attempt to read or interpret "holes".

The cards will, in addition to producing the BV 588 report, be used for several other purposes, such as compilation of retirement data, special valuations for leases, sales, trackage right agreements or other studies that require data relating to the investment cost of a particular piece of property or groups of properties. The cards will also serve as a permanent property record of the installation as the current card, when filed with other cards pertaining to the same property, will give its complete historical record and the costs pertaining thereto.

* All exhibits are presented at end of report.

Sample Tabulated Completion Reports

The printed completion reports (Exhibit B) illustrating several types of roadway construction projects were prepared on a printing tabulator. To demonstrate the capacity and flexibility of the equipment, completion reports were selected to show:

1. Track constructed to serve the United States Government.
2. Replacement of bridge pier and installation of sheet piling.
3. Construction of freight house and office building.
4. Highway street crossing flasher equipment, including short arm gates.

To permit a more detailed examination of the several reports, reference letters have been inserted along the left hand margin of the Exhibit B.

1. *Track Completion Report. (Sheet 1)*

A. Items typed in after the report has been completed.
(Note: In the Electric Typewriter-Key Punch combination the unit controls would be arranged so no cards would be produced for these items).

B. Items needed as identification or special information on the completion report, which are not required in the BV 588 report. These cards are rejected or discarded after the tabulated completion report has been producd. (See comment under item A).

C. Detail of the property units installed with their related costs. The use of standardized single line descriptions is required. The spacing is arranged and controlled by the various sub-titles (card fields) on the Completion Report Punch Card (Exhibit A) Cols. 21 to 55.

D. Detail of the property units retired with their related costs.

2. *Bridge Completion Report. (Sheet 2)*

A. and B., same as shown for track completion report (Item 1).

C. Detail of property units installed with their related costs. Structural property requires individualized reporting by individual structures on the BV 588. Instructions have been issued to reduce the descriptive information to the bare minimum, having in mind the requirements of the BV 588. This is necessary to keep the cards to the absolute minimum as each line on the Completion Report requires a separate card.

D. Detail of retirement units with their related costs. It will be noted that under this group several items are identified by a "v" in the narrow column. These items are those that were included in the ICC Basic Valuation and are a part of the required reporting for the BV 588 returns.

3. *Construction of Freight House, etc. (Sheets 3 and 4)*

A. and B., same as shown under track completion report. (Item 1)

C. Detail of the property units installed with their related costs. Here it will be noted a considerable effort has been expended toward instructing the engineers, who prepare the pencil completion report, to keep descriptions to the minimum, and wherever possible to use a single line. The units shown are those required by Valuation Order 3 regulations, covering the BV 588, with costs broken down between contract and company installations. The recapitulation summary, on Sheet 4, indicates that the retirements in connection with this project were handled on a previous completion report.

4. *Highway Crossing Flashers, etc. (Sheets 5 and 6)*

A. and B., same as shown for track completion report. (Item 1)

C. Detail of property units installed with their related costs. The cost reported on this project is quite complicated, involving as it does part payments by the state and the need for showing total costs, as well as costs borne by the carrier. The use of signal adjustment units in Account 27 allows extensive savings in descriptive information. These signal adjustment units are those specified by the Signal Section, AAR.

D. Detail of retirement units and their related costs. Here again we see retirements from the Basic Valuation as well as retirements from Valuation Order 3 work.

Sample Tabulated Completion Reports—General

From the sample detail shown on the Completion Reports in Exhibit B for various types of work we may plainly see that the accounting engineers, who prepare the pencil completion reports, use standardized descriptions for the mass items (track work) and brief descriptions for structural items. The procedures followed in the preparation of the Completion Report under the mechanized system are no different than the ordinary procedures generally followed, except that the descriptive information must conform with the standardized procedures so machine sorting may be utilized in handling the tabulating cards.

On the road studied, the pencil completion report is forwarded from the accounting engineer to the assistant valuation engineer for review and restatement of retirement costs where necessary. After this review, the report is sent to the office of the auditor of expenditures, under whose supervision the tabulating equipment is operated, and is routed to the key punch department. The tabulating cards are verified and then sent to the machine room (printing tabulator), where the completion report is printed, using a continuous fan fold form producing the required number of carbon copies. The entire file (pencil completion report, printed completion report and tabulating cards) is then returned to the accounting engineers for checking. If any corrections are required they are made on the typewriter in the accounting engineer's office and corresponding corrections are made in the tabulating card set. As already indicated, the necessary headings (Items A's) are filled in on the typewriter.

It may readily be seen that with a typewriter-key punch combination a number of the above described steps might be eliminated, and that with proper card cutting control produce only the cards one may require for the BV 588 procedure. Check controls are established to be sure the cards add to proper totals for each account and for proper net booked changes under each project.

Preparation of the BV 588 Report

After all the completion reports for a valuation section have been made, a clearance is requested from the auditor of capital expenditures, to indicate if the total audits for the section will agree with the totals cumulated on the completion reports. After this clearance is obtained and the card totals checked, the punched cards for the section are sorted into primary accounts and then sub-sorted into proper groups under the account, with master header cards inserted where necessary. Each similar item of mass property is, in this manner, brought together so the machine might be able to add the cards and print a single total (units and amounts for the entire group). In the structural accounts

the process is similar, except each card is printed having first been brought together with all the other cards relating to an individual bridge, building or other structure, machine, etc.

BV 588 Report Form

As the spacing of the printing tabulating machine does not conform to normal typewriter spacing, permission was obtained to make the necessary alterations in spacing and column arrangement on the BV 588 form, so the tabulation equipment could be used. The sheets are furnished in continuous fanfold style with the necessary number of carbons. Heading information is inserted by a standard typewriter, as in the case of the pencil completion report.

Sample BV 588 Report Sheets

Sample sheets from an actual BV 588 report are attached as Exhibit C. While not all the accounts are included, enough samples are shown to give a good idea of the appearance of the finished product. As different accounts require different treatment, the following few comments are presented pertaining to items of special interest:

General Sheet (Title, Engineering and General Accounts) Exhibit C, Sheet 1

This sheet is prepared by separately punched cards to show, as required by the BV 588 instructions, the list of account numbers being reported upon; the mileage at the start and end of the period; and for Accounts 1, 71 to 75, and 77 and 76 the total in money only. The printing for the monies in each of these accounts is accomplished by the equipment accumulating the totals from each card and printing a single line result.

Mass Property Sheets (Accounts 3–8–9 and 10) Exhibit C, Sheet 2 and 3

On these two pages is displayed the mass property changes for typical track work on a valuation section during the sample year. In all cases the printed results represent an accumulation of changes and may be a single card or many cards. To allow the automatic printing at the start and end of each account, heading and trailer cards were inserted. To meet the requirements of the regulations it will be noted that in many cases both the unit count and the weight total is shown for the item. The use of the standard short descriptive identifications with positive position spacing is clearly demonstrated on these two sheets.

Structural Property Sheets (Accounts 16, 17, 20, 26 and 27) Exhibit C, Sheets 4, 5 and 6

In Account 16, Station and Office Buildings, the clear advantage of short descriptions is brought forth. Retirements are shown from three locations, Oliver, Robinson and Birds, with short but clear identification to the original source of the item being retired. In Account 17, it can be seen how two lines are all that is necessary to positively identify a $1,258 building being retired. The Account 20 item is not complete but shows the start of a report on an extension to an existing facility.

In Accounts 26 and 27 we have typical items improving existing electrical equipment.

Summaries

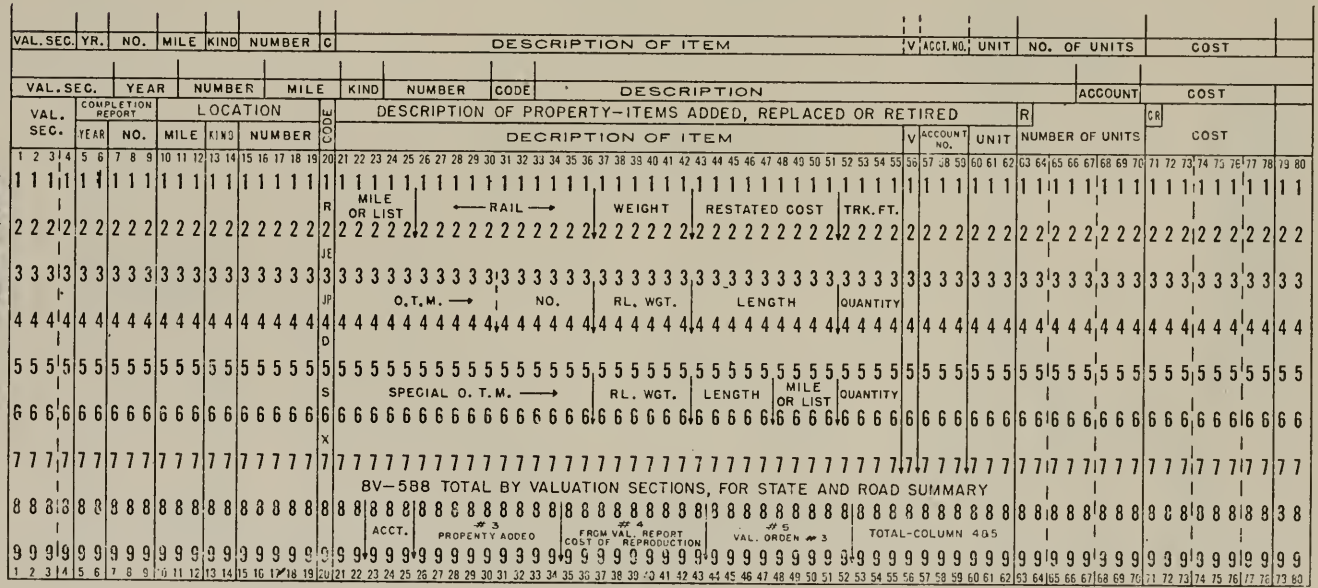
A. Summary Developed From Detail Tabulating Cards

After the cards have been used to produce the detail BV 588 sheets they are again run through the tabulator to produce a summary for the valuation section. With the printing of the summary sheet a special attachment connected with the tabulator will

(Test continued on page 638)

EXHIBIT A Sheet 1 of 1

Completion Report Punch Card.



ROADWAY COMPLETION REPORT EXHIBIT B Sheet 1 of 6

GENERAL ACCOUNTS I, ROAD AND III. GENERAL EXPENDITURES

Line

[redacted] RAILWAY COMPANY (NAME OF CARRIER) A. F. E. No. 73321

Owner [redacted] Date Approved 3-20-50

Lessee [redacted] Vol. Sec. No. 26

Operating Company [redacted] Station Moraine State Ohio

A Cost borne by Carrier Cha. Sta. or M. P.

Work herein reported begun 6-11-51 Final Report 351-100

Work herein reported completed 8-30-51 Portion herein reported {turned over to / retired from} operation 8-30-51

DESCRIPTION OF PROJECT Construct Track to serve the U. S. Government, Work performed by Carrier Forces (CONTRACT OR CARRIER FORCES)

This report of property changes which were made under my supervision, is true to the best of my knowledge and belief.

CORRECT (Sgt.) [redacted] Auditor of Expenditures (Sgt.) [redacted] Div. Engineer

	DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS (If by contract, date and name of Contractor)	V	ACCT. NO.	PROPERTY UNITS UNIT	PROPERTY UNITS NO. OF UNITS	COST ADDED	COST RETIRED
B	ADDITION						
B	SIDE TRACK LIST 661						
	PS IN LIST 860						
	PCT TF						
	BUILT NEW 100 225						
B	BUILT NEW 0 1816						
	TOTAL LENGTH 2041						
B	225 TF PORTION						
	CROSS TIES TREATED		8	EA	70	19600	
	SWITCH TIES TREATED		8	MBM	3844	16069	
C	RAIL RELAY 90LB 88		9	GT	8360	8260	
	RAIL RELAY 105LB 114		9	GT	3370	12495	
B	DESCRIPTION NO						
	FROG SW NO 8 90LB 7.0FT 1		10	CWT	8300	8000	
	SWITCH HEINF 90LB 16.2FT 1		10	CWT	10	2000	
	SWITCH STAND LOW 1		10	CWT	2	200	
C	CG RAIL TITAN 90LB 6.5FT 1		10	CWT	5	500	
	CG RAIL G C 90LB 6.0FT 1		10	CWT	1900	500	
	JOINTS Rest SH		10	CWT	7830	1000	
	JOINTS COMP SH 105LB 90LB 2		10	CWT	1360	200	
	SPIKES		10	CWT	5	3296	
	BOLTS		10	CWT	670	844	
	TIE PLATES 213		10	CWT	28780	21130	
	NUTLOCKS		10	CWT	50	317	
C	BALLAST CINDERS		11	CY	40	2108	
	TRACKLAYING 90LB TO 120LB RAIL		12	MI	43	941 76	
	PLACING TURNOUT		12	EA	1		
C	PLACING TIE PLATES		12	EA	213		
	PLACING BALLAST CINDERS		12	CY	40		
B	RETIREMENT LEDGER VALUE						
B	INST AFE 9305 CR 483 YR 2 1939						
	ENGINEERING		1				27
D	INTEREST DURING CONSTRUCTION		76				61
B	SIDE TRACK LIST 860						
	CROSS TIES TREATED		8	EA	48		9600
D	TRACKLAYING ACCOUNT TIES		12				1440
B	TOTAL RE					165695	
	TOTAL RE						111188.

SUMMARY OF ACCOUNTS

	DEBITS	CREDITS	NET		
		0.87	0.87CR	1	
B	356.69	96.00	260.69	8	
	207.55		207.55	9	
	129.87		129.87	10	
	21.08		21.08	11	
	941.76	14.40	927.36	12	
		0.61	0.61CR	76	

A. F. E. No. 73321 Sheet No. 1 of 2 Sheets Completion Report No. 351-100

ROADWAY COMPLETION REPORT

EXHIBIT B Sheet 2 of 6

GENERAL ACCOUNTS I, ROAD AND III. GENERAL EXPENDITURES

[redacted]
(NAME OF CARRIER)

A F E No. 72953

Owner [redacted]

Date Approved 10-17-50

Lessee [redacted]

Vol. Sec. No 6

Operating Company [redacted]

Station E. Alton

State Ill.

Cost borne by Carrier

Cha. Sta. or M. P.

A Work herein reported begun 7-9-51

Progress or Final Report B51-353

Work herein reported completed 9-31-51

Portion herein reported { turned over to / retired from } operation 9-31-51

DESCRIPTION OF PROJECT Replace pier #2 and install sheet piling protection around pier #1.

Work performed by both (CONTRACT OR CARRIER FORCES)

This report of property changes which were made under my supervision, is true to the best of my knowledge and belief

CORRECT (Sgd.) [redacted] Auditor of Expenditures [redacted] Dist. Engineer

	DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS If by contract date and name of Contractor	V	ACCT NO	PROPERTY UNITS UNIT	NO. OF UNITS	COST ADDED	COST RETIRED
B	ADDITION						
C	ENGINEERING		1			75056	
	DEPR PROPERTY 750.56		6				
	MILE 240 BRIDGE 553						
C	BRIDGE 553 OVER WOOD RIVER						
	D P C ER PAGE 141						
C	REPLACE PIER NO 2 AND INSTALL						
C	SHEET PILING PROTECTION PIER NO 1						
	PIER NO 2						
	SUBSTRUCTUR						
	PILING TREATED		J 6	LF	1300	380292	
	CONCRETE PLAIN		J 6	CY	118	817776	
C	CONTR COST CLASS A CY 80.70		J 6				
	CONTR COST CLASS C CY 55.10		J 6				
	REINFORCING BARS		J 6	LB	830	16600	
	CONTR COST LB 0.20		J 6				
	SHEETING STEEL PERM UNITED STATES		J 6	LB	88244	404677	
	CONTR COST NT 286.56		J 6				
	SHEET PILE PROTECTION PIER NO 1						
	SUBSTRUCTUR						
	CONCRETE PLAIN		J 6	CY	14	108573	
	CONTR COST CY 75.10		J 6				
C	REINFORCING MESH		J 6	LB	54	3000	
	CONTR COST SF 0.10		J 6				
	SHEETING STEEL PERM UNITED STATES		J 6	LB	2763	464954	
	CONTR COST NT 336.56		J 6				
B	RETIREMENT EST LEDGER VALUE RESTATED COST						
	ENGINEERING 121.00*	V	1				12144 x
D	INTEREST DURING CONST 223.00*	V	76				x
B	MILE 240 BRIDGE 553						
	PIER NO 2						
	SUBSTRUCTUR						
D	MASONRY STONE ASHLARE	VJ	6	CY	140		169000
D	MASONRY CONCRETE PLAIN	VJ	6	CY	650		4900
	GRILLAGE OAK	VJ	6	MBM	10500		42000
	PILING OAK	VJ	6	LF	1773		88700
B	RETIREMENT LEDGER VALUE						
B	INST AFE 1225 CR 20 YR 1 1919						
	CONCRETE PLAIN		J 6	CY	30		55000
D	REINFORCING BARS		J 6	LB	35		400
	TOTAL RE					2370928	
	TOTAL RE						3709.44

SUMMARY OF ACCOUNTS

	DEBITS	CREDITS	NET		
	750.56	121.44	649.12	1	
B	21958.72	3588.00	18370.72	6	
	0.00		0.00CR	76	
	22709.28	3709.44	18999.84	TOTAL	
			2405.00	270	

A F E No 72953 Sheet No 1 of 2 Sheets Completion Report No B51-353

ROADWAY COMPLETION REPORT EXHIBIT B Sheet 3 of 6

GENERAL ACCOUNTS I, ROAD AND III. GENERAL EXPENDITURES

LEC

[redacted] (NAME OF CARRIER) A. F. E. No. 69107-01

Owner [redacted] Date Approved 1-19-49

Lessee [redacted] Vol. Sec. No. 14

Operating Company [redacted] Station LaFayette State Ind.

A Cost borne by Carrier Cha Sta. or M. P.

Work herein reported begun 10-30-50 [redacted] Final Report B51-400

Work herein reported completed 8-31-51 Portion herein reported {turned over to / retired from} operation 8-21-51

DESCRIPTION OF PROJECT Construction of Freight House Office Building. Work performed by Both (CONTRACT OR CARRIER FORCES)

This report of property changes which were made under my supervision, is true to the best of my knowledge and belief.

CORRECT: [redacted] (Signature) Auditor of Expenditures (Title) [redacted] (Signature) Dist. Engineer (Title)

	DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS If by contract, date and name of Contractor	V	ACCT NO	PROPERTY UNITS UNIT	PROPERTY UNITS NO OF UNITS	COST ADDED	COST RETIRED
B	ADDITION						
	ENGINEERING		1			139178	
C	DEPR PROPERTY 1391.7M		16				
B	MILE 174 BLDG 198						
	FREIGHT HOUSE OFFICE NO 198		16	EA	1		
	GLAZED TILE 51 0X44 0 X11 2 VOL		16				
	25065 CF BUILT UP ROOF ON KAYLOR		16				
	ROOF TILE OPENINGS 4475F REINF		16				
	CONCRETE FLOOR WITH TILE ON 1045		16				
C	SF STRUCTURAL TILE PARTITIONS		16				
	SCREENS FOR DOORS AND WINDOWS						
	DIST ENGRS PLANS 32R09 TO 32M16		16				
	CONTR COST LUMP SUM 38658.51		16				
	FOUNDATION EXCAVATION DRY		16	CY	58		
C	FOUNDATION CONCRETE PLAIN		16	CY	58		
	FOUNDATION REINFORCING BARS		16	CY	1108		
	PLUMBING						
	SERVICE SINK CRANE PORCELAIN		16	EA	1		
	DRINKING FOUNTAIN CURWITH		16	EA	1		
	LAVATORY KOHLER		16	EA	2		
	TOILET SANTO		16	EA	3		
	URINAL CURRECTO		16	EA	2		
	STALL PARTITIONS WEISTEEL		16	SF	115		
C	DRINKING FOUNT MALSBY TAYLOR ELECT		16	EA	1		
	FLOOR DRAINS 3IN		16	EA	1		
	HEATING AMERICAN STANDARD HOT WATER		16	SFR	967		
	BOILER NO A 5555 WITH PETRO OIL		16				
	BURNER AND 1000 GAL OIL STORAGE		16				
	TANK		16				
	LIGHTING ELECTRIC		16	OLT	35		
	9 RLM DOME FIXTURES FURNISHED BY RR		16				
C	PLATFORM 6IN CONCRETE ON 4FT GRAVEL FILL		16	SF	55		
	STAIRS CONC 12IN TREAD 6IN RISER		16	LF	20		
	RAILING TWO PIPE RAILS 1.5 IN AND PIPE POSTS		16	LF	20		
	PLATFORM 2IN YP DECK		16	SF	176		
	FOUNDATION TIMBER YP		16	MBM	600		
C	STAIRS YP 12IN TREAD 8IN OPEN RISER		16	LF	48		
	RAILING YP 2 IN X 2 IN RAILS ON 4 IN X 4 IN POSTS		16	LF	50		
	SIDEWALK 5IN CONCRETE		16	SF	185		
	SEWER VIT PIPE 6IN EXCAV 3FT		16	LF	30		
	WATER C I PIPE 1.5IN EXCAV 3FT		16	LF	160		
	TOTAL					393781	
	SHELVING AND FILE CABINETS		16				
	FRAMING Y P		16	MBM	1304		
C	CABINETS PLYWOOD MFT X 3FT X 3FT WITH STAINLESS STEEL TOP		16	EA	1		
	TOTAL					60980	
	FURNITURE		16	LOT	1	58655	
	2 EXTINGUISHER FIRE DIENER 5 GAL		16				
C	1 EXTINGUISHER DRY MOD 7.5		16				
	5 34 X 60 METAL DESKS		16				
	1 34 X 82 OAK DESK		16				
	1 1M X 68 OAK TABLE		16				

A. F. E. No. 69107-51 Sheet No. 1 of 2 Sheets Completion Report No. B51-400

ROADWAY COMPLETION REPORT

GENERAL ACCOUNTS I, ROAD AND III. GENERAL EXPENDITURES

EXHIBIT B Sheet 4 of 6

THE NEW YORK CENTRAL RAILROAD COMPANY
(NAME OF CARRIER)

A. F. E. No. 69107-01

Owner

Date Approved 1-19-49

Lessee

Vol. Sec. No. 14

Operating Company

Station LaFayette State Ind.

Cost borne by

Cha. Sta. or M. P.

Work herein reported begun

Final Report 891-400

Work herein reported completed

Portion herein reported { turned over to / retired from } operation

DESCRIPTION OF PROJECT

Work performed by
(CONTRACT OR CARRIER FORCES)

This report of property changes which were made under my supervision, is true to the best of my knowledge and belief

CORRECT: _____ _____ _____ _____
(Signature) (Title) (Signature) (Title)

	DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS If by contract, date and name of Contractor	V	ACCT NO	PROPERTY UNITS UNIT	PROPERTY UNITS NO. OF UNITS	COST ADDED	COST RETIRED
	1 28 X 26 X 32 IRON SAFE		16				
C	3 15 X 24 X 48 OAK FILE CABINET		16				
	2 18 X 28 X 52 METAL FILE CABINET		16				
	1 36 X 21 X 76 METAL CABINET		16				
	5 SWIVEL CHAIRS OAK		16				
	1 STRAIGHT CHAIR OAK		16				
	OFFICE EQUIPMENT						
C	BURROUGHS 13 BANK ADDING MACH GM		16	EA	1	4500	
C	UNDERWOOD FANFOLD BILLING MACHINE		16	EA	2	50695	
	COMMUNICATION SYSTEMS		26				
	WAY SIDE TELEPHONE INSTALLATION		26	FA	1	104660	
	TYPE C 1A INCLUDING ONE		26				
C	SELECTOR 17 STEP 60 AP		26				
	UNDERGROUND CONDUIT RI PIPE 2 IN		26	LF	70	2324	
	UNDERGROUND CABLE		26				
C	CABLE ARMORED 24PR 12 QUADS		26	LF	85	21516	
	16 GA TYPE 775 AP		26				
	TOTAL RF					4401489	
	SUMMARY OF ACCOUNTS						
	DEBITS CREDITS NET						
	THIS REPORT						
	1391.78 1391.78		1				
B	41128.11 41128.11		16				
	1495.00 1495.00		26				
	44014.89 44014.89		TOTAL				
	RECAPITULATION TO DATE						
	1391.78 897.19 494.59		1				
B	41128.11 30767.87 10360.24		16				
	1495.00 1495.00		26				
	8687.35 8687.35CR		37				
	44014.89 40352.41 3662.48		TOTAL				
	1653.23		870				
B	NOTE FOR ADDITIONAL COSTS TO THIS AFE SEE 846 387 847 195						

A. F. E. No. 69107-01 Sheet No. 2 of 2 Sheets Completion Report No. 891-400

ROADWAY COMPLETION REPORT EXHIBIT B Sheet 5 of 6
GENERAL ACCOUNTS I, ROAD AND III. GENERAL EXPENDITURES

[redacted] (NAME OF CARRIER) A. F. E. No. 72851-02

Owner [redacted] Date Approved 9-11-50

Lessee [redacted] Vol. Sec. No. 4

Operating Company [redacted] Station Kansas State Illinois

A Cost borne by Carrier Cha. Sta. or M. P.

Work herein reported begun 11-27-50 Previously reported Final Report B51-127

Work herein reported completed 1-24-51 Portion herein reported {turned over to / covered from} operation 1-24-51

DESCRIPTION OF PROJECT Install Flashing Light Signals and Electric Gates at Front Street and retire existing protection. Work performed by carrier forces. (CONTRACT OR CARRIER FORCES)

This report of property changes which were made under my supervision, is true to the best of my knowledge and belief.

CORRECT: (Sgd.) [redacted] Auditor of Expenditures (Sgd.) [redacted] Asst. Signal Engineer

	DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS If by contract, date and name of Contractor	V	ACCT. NO.	PROPERTY UNITS UNIT	PROPERTY UNITS NO. OF UNITS	COST ADDED	COST RETIRED
B	ADDITION JOINT PROJECT						
C	ENGINEERING		1				
	DEPR PROPERTY 91.18		27				
	TOTAL COST 196.22		1				
C	PAID BY STATE OF ILL 105.04		1				
	PAID BY CARRIER ()		1			91 18	
B	MILE 105 CS 5505 FRONT ST		27				
	HIGHWAY CROSSING PROTECTION						
	SAU		27				
	30		27	LF	3270		
	3081		27	C DF	9396		
C	53A1		27	EA	5		
	11302		27	EA	8		
	115A		27	AH	2480		
	41181		27	EA	4		
	453A1		27	EA	1		
	535		27	LB	559		
	957A1		27	EA	2		
	959A1		27	FA	2		
	RELAY CASE WIRED FOR		27	FA	1		
	TYPE B RELAYS		27				
	TYPE B RELAYS		27	FA	24		
	END OF CIRCUIT SIGNS		27	FA	1		
	PINS AND INSULATORS		27	FA	130		
	CROSSARMS		27	EA	4		
	DEAD ENDS		27	EA	31		
	TOTAL COST 14413.55		27				
C	PAID BY STATE OF ILL 7745.13		27				
	PAID BY CARRIER		27			6668 42	
	CCCSTL RY CO 100.PCT						
B	BETTER-MENT MAIN TRACK NO LOCATION						
B	NO RL WGT LGTH NU						
C&D	JOINTS CON N HEAT TREATED		10	C WT	4530		26 36
	JOINTS CONT N 127LB 38 INSL 4		10	C WT	8800	100 36	
	RESTATED COST						
	BOLTS 1.00*	V	10	C WT	360		397X
B	BETTERMENT SIDE TRACK NO LOCATION						
	NO RL WGT LGTH NU						
	JOINTS CON N HEAT TREATED		10	C WT	12220		7057
C&D	JOINTS CONT N 127LB 3H INSL 5		10	C WT	11	12545	
	JOINTS CONT N 105LB 36 INSL 9		10	C WT	13760	17723	
	BOLTS 3.00*	V	10	C WT	1170		1291X
B	RETIREMENT EST LEDGER VALUE						
	RESTATED COST						
	ENGINEERING 20.00*	V	1				2046X
D	INTEREST DURING CONST 40.00*	V	76				X
B	MILE 105 CS 5505 FRONT ST		27				

A. F. E. No. 72851-02 Sheet No. 1 of 2 Sheets Completion Report No. B51-127

ROADWAY COMPLETION REPORT EXHIBIT B Sheet 6 of 6

GENERAL ACCOUNTS I, ROAD AND III. GENERAL EXPENDITURES

THE NEW YORK CENTRAL RAILROAD COMPANY
(NAME OF CARRIER)

A. F. E. No. 78851-02

Owner — Date Approved

Lessee — Vol. Sec. No. 4

Operating Company — Station [redacted] — State Illinois

A Cost borne by — Chg. Sta. or M. P.

Work herein reported begun [redacted] Final Report 1931-107

Work herein reported completed — Portion herein reported {turned over to / retired from} operation

DESCRIPTION OF PROJECT — Work performed by (CONTRACT OR CARRIER FORCES)

This report of property changes which were made under my supervision, is true to the best of my knowledge and belief.

CORRECT: (Signature) (Title) (Signature) (Title)

	DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS If by contract, date and name of Contractor	V	ACCT NO	PROPERTY UNITS UNIT	PROPERTY UNITS NO. OF UNITS	COST ADDED	COST RETIRED
D	CROSSING GATE 363.000	V	27	EA	2		36250X
	ELLIOTT PNEU ER PG 58 PART ITEM 13	V	27				
B	MILE 108 BLDG 48	V	27				
	AERIAL TOWER NO 48 COMPLETE	V	27	EA	1		11300
D	ER PAGE 58	V	27				
D	MISCELLANEOUS IMPROVEMENTS COMPLETE	V	27	EA	1		3600
	INCLUDING BLDG NO 807 ER PG 52	V	27				
B	RETIREMENT LEDGER VALUE						
B	INST APP 44963 1 ER 271 YR 1930						
B	MILE 105 88 5808 FRONT ST		27				
	HIGHWAY CROSSING PROTECTION						
	BAN		27				
	3081		27	SF	1870		
D	41181		27	EA	1		
	MERCURY CIRCUIT CONTROLLER		27	EA	2		
	WORK CO NO 1008		27				
	CROSSING GATE LAMPS		27	EA	4		
	WORK CO NO 1863		27				
	TOTAL		27				17834
	PAGE 19 OF 808 RETURNS YEAR 1930		27				
	PART OF 916.83		27				
B	TOTAL RE					71682	
	TOTAL RE						89411

SUMMARY OF ACCOUNTS

DEBIT	CREDIT	NET		
91.18	20.46	70.72	1	
403.04	113.81	289.23	10	
B 6660.48	609.84	5978.58	27	
	0.88	0.88	76	
7160.84	894.11	6338.53	TOTAL	
		87.81	270	

A. F. E. No. Sheet No. of Sheets Completion Report No.

B. V. Form No. 588-R

REPORT TO INTERSTATE COMMERCE COMMISSION
BUREAU OF VALUATION

Owner [redacted]
Operating company [redacted]
Valuation section 8-Illinois

(Name of reporting carrier)

Statement showing property changes from Jan. 1, 1951 to Dec. 31, 1951

Sheet No. ____ of ____ sheets for this valuation section.

Character of property and description	Units	Property added: Number of units (decimal)	Property added: Cost	Property added: Per unit		Property retired: Number of units (decimal)	Property retired: Cost	Cost of reproduction New	
Account No. ____ Title ____ (I. C. C. Classification)									
THIS REPORT INCLUDES ACCOUNTS 1 2 3 6 8 9 10 11 12 16 17 20 26 27 39 44 AND 76									
AS OF MILEAGE STATEMENT JAN 1.1951 DEC 31.1951									
1ST MAIN		130.539	130.539						
2ND MAIN		20.965	20.965						
Y T AND S		97.539	97.803						
		0.028*	0.028*						
TOTAL ALL TRKS		249.043	249.307						
		0.028*	0.028*						
NOTE * DENOTES JOINT									
ACCT 1 ENGINEERING									
ENGINEERING			33291				10175	112	
ACCT 76 INTEREST DURING CONSTR									
INTEREST DURING CONST							1866	281	

Columns 5, 6 and 10 should be left blank by the reporting carrier. Show on the first sheet of each valuation section, a statement of the account numbers included in the report, a statement showing the changes in mileage, and a sworn statement as to the correctness of the report.

EXHIBIT C Sheet 1 of 6

B. V. Form No. 388-R

REPORT TO INTERSTATE COMMERCE COMMISSION
BUREAU OF VALUATION

Owner [redacted]
Operating company [redacted] (Name of reporting carrier)
Valuation section No. 8-Illinois Statement showing property changes from Jan. 1, 1952 to Dec. 31, 1952

Sheet No. ____ of ____ sheets for this valuation section.

Character of property and description	Units	Property added: Number of units	Property added: Cost	Property added: Per unit	Property retired: Number of units	Property retired: Cost	Cost of reproduction New
Account No. ____ Title (I. C. C. Classification)							
ACCT 3 GRADING							
GRADING COMMON	CY				860		
TOTAL						549 47	
ACCT 8 TIES							
ALL TRACKS							
CROSS TIES TREATED	EA	1673			986		
SWITCH TIES TREATED	MBM	24 423			10259		
~~SWITCH TIES~~ ~~UNTR~~	~~MBM~~				10508		
CROSSING TIES TREATED	MBM	192					
TOTAL			6720 56			2672 12	
ACCT 9 RAILS							
	TRACK FEET ADDED / RETIRED						
MAIN TRACK							
~~RELAY 127LB~~	146	~~CT~~ 5 520					
RELAY 105LB	146	CT			4560		
YARD TRACKS AND SIDINGS							
RELAY 105LB	23253	CT 150 720					
RELAY 90LB	100 1861	CT 2 680			49820		
RELAY 80LB	1691	CT			40270		
TOTAL			5658 09			2210 40	

Columns 5, 6 and 10 should be left blank by the reporting carrier. Show on the first sheet of each valuation section, a statement of the account numbers included in the report, a statement showing the changes in mileage, and a sworn statement as to the correctness of the report

EXHIBIT C Sheet 2 of 6

B V Form No. 588-R

REPORT TO INTERSTATE COMMERCE COMMISSION
BUREAU OF VALUATION

Owner [redacted] Sheet No ___ of ___ sheets for this valuation section

Operating company [redacted] By [redacted]
(Name of reporting carrier)

Valuation section 8 Illinois Statement showing property changes from Jan. 1, 1951 to Dec. 31, 1951

Character of property and description	Units	Property added: Number of units	Property added: Cost	Property added: Per unit	Property retired: Number of units	Property retired: Cost	Property retired: Cost of reproduction New
Account No ___ Title ___ (I. C. C. Classification)							
ACCT 10 STHER TRACK MATERIAL							
ALL TRACKS							
	NUMBER ADDED RETIRED						
FROGS RIGID RC	1 5	CWT	10		75250		
FROGS SOLID MANG SC	6 1	CWT	67 200		8900		
SWITCHES REINFWRCED	7 6	CWT	145 250		97500		
SWITCH STANDS	7 6	CWT	14		12		
SWITCH LOCKS		EA			1		
CROSSING FROG RB	1	CWT	70				
GUARD RAIL CSW	6	CWT			54430		
GUARD RAIL PAT	2	CWT			4100		
JOINT CSW NEW HT TR		CWT			5940		
JOINT COMMON RELAY		CWT	260 810		163730		
JOINT PAT NEW	20	CWT			20280		
JOINT PAT INS NEW	3 3	CWT	5 160		2700		
JOINT COMP NEW	6 2	CWT	5 440		1220		
JOINT COMP RELAY	4	CWT	3 200				
SPIKES DRIVE		CWT	90		38940		
SPIKES SCR		CWT	5 900				
BOLTS		CWT	13 870		10790		
TIE PLATES	7287 2660	CWT	955 70		305050		
NUTLOCKS		CWT	1 10		490		
ANTICREEPERS	2200	CWT	66				
GAUGE RODS		CWT			1150		
TOTAL			772535			203373	

Columns 5, 6 and 10 should be left blank by the reporting carrier. Show on the first sheet of each valuation section, a statement of the account numbers included in the report, a statement showing the changes in mileage and a sworn statement as to the correctness of the report

EXHIBIT C Sheet 3 of 6

B V Form No. 588-R

REPORT TO INTERSTATE COMMERCE COMMISSION
BUREAU OF VALUATION

Owner [redacted]
Operating company [redacted] (Name of reporting carrier)
Valuation section 8-Illinois

Sheet No. ____ of ____ sheets for this valuation section

Statement showing property changes from Jan. 1, 1951 to Dec. 31, 1951

Character of property and description	Units	Property added: Number of units	Property added: Cost	Property added: Per unit	Property retired: Number of units	Property retired: Cost	Cost of reproduction New
Account No. Title (I C C Classification)							
ACCT 16 STATION AND OFFICE BLDGS							
OLIVER							
MISCELLANEOUS IMPROVEMENTS COMPLETE	LOT				1		507
ER PAGE 227							
ROBINSON							
FREIGHT HOUSE NO 124							
PLATFORM RAISED TIMBER 21IN DECK	SF				1560		
FOUNDATION TIMBER YP	MBM				1912		
PAGE 87 OF 588 RETURNS 1915 27							
TOTAL						39990	
BIRDS							
COMBINATION PASS AND FRT STA NO 139							
BUILDING FRAME	CF				14640	235903	
FOUNDATION EXCAVATION DRY	CY				64	3220	
FOUNDATION CONCRETE CLASS C	CY				42	34808	
PLATFORM LOB CONC 41N	SF				3057	24154	
PLATFORM CURB CONC 6IN X 30IN	LF				316	19301	
PLATFORM STONE SCREENINGS	CY				333	54533	
PLATFORM CINDERS	CY				103	15976	
PLATFORM CURBING CONC	LF				249	51521	
PAGE 88 OF 588 RETURNS 1915 27							

Columns 5, 6 and 10 should be left blank by the reporting carrier. Show on the first sheet of each valuation section, a statement of the account numbers included in the report, a statement showing the changes in mileage, and a sworn statement as to the correctness of the report

EXHIBIT C sheet 4 of 6

B. V. Form No. 588-R

REPORT TO INTERSTATE COMMERCE COMMISSION
BUREAU OF VALUATION

Owner [redacted]

Operating company [redacted]
(Name of reporting carrier)

Valuation section 8-Illinois

Sheet No ____ of ____ sheets for this valuation section

Statement showing property changes from Jan. 1, 1951 to Dec. 31, 1951

Character of property and description	Units	Property added: Number of units (decimal)	Property added: Cost	Property added: Per unit		Property retired: Number of units (decimal)	Property retired: Cost (cents)	Cost of reproduction New	
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Account No. ____ Title (I. C. C. Classification)									
ACCT 17 ROADWAY BUILDINGS									
ST FRANCISVILLE									
PUMPERS DWELLING NO 305 COMPLETE PAGE 10 OF 588 RETURNS 1932	EA					1	125800		
TOTAL							125800		
ACCT 20 SHOPS AND ENGINEHOUSES									
MT CARMEL									
LOCKER AND TOILET ROOM NO 420 CONCRETE BLOCK FORMERLY WOMENS REST ROOM EXTENSION 16FT X 24FT X 9FT 6IN CONCRETE BLOCK BUILT UP ROOF OPENINGS 97 SF CEILING CELATEX WALL BOARD 6IN CONCRETE FLOOR INTERIOR PAINTED 3 COATS EXTERIOR 2 COATS	CF	4126							
FOUNDATION EXCAVATION DRY	CY	27							
FOUNDATION CONCRETE PLAIN	CY	9							
FOUNDATION REINFORCING BARS	LB	325							

Columns 5, 6 and 10 should be left blank by the reporting carrier. Show on the first sheet of each valuation section, a statement of the account numbers included in the report, a statement showing the changes in mileage, and a sworn statement as to the correctness of the report

EXHIBIT C Sheet 5 of 6

B. V. Form No. 508-R

REPORT TO INTERSTATE COMMERCE COMMISSION
BUREAU OF VALUATION

Owner [illegible]

Operating company [illegible]

Valuation section 8-Illinois

(Name of reporting carrier)

Statement showing property changes from Jan. 1, 1951 to Dec. 31, 1951

Sheet No. ____ of ____ sheets for this valuation section

Character of property and description	Units	Property added: Number of units	Property added: Cost	Property added: Per unit	Property retired: Number of units	Property retired: Cost	Cost of reproduction New
Account No. ____ Title (I. C. C. Classification)							
ACCT 26 COMMUNICATION SYSTEMS							
TELEPHONE OFFICE APPARATUS							
2 SELECTOR 160A 1 GENERATOR 299F	SET				1		
TELEPHONE OFFICE APPARATUS	EA				2		
LYONS YD TO MT CARMEL							
BOX JACK POLE LINE TYPE 17A	EA	68					
WITH ASSOCIATED EQUIPMENT							
TOTAL			240881			25672	54
ACCT 27 SIGNALS AND INTERLOCKERS							
DANVILLE DYTON ELEC INTERLOCKER							
ELEC LIGHTING NB APPROACH SIGNAL							
S A U							
30	LF	25					
30 8 1	CFT	75					
115	AH	1000					
LIGHTING UNIT A W 1184	EA	1					
TOTAL			4805				
PARIS PENNA ELEC INTERLOCKER							
ELEC LIGHTING NB APPROACH SIGNAL							
S A U							
30	LF	25					
30 8 1	CFT	75					
115	AH	1000					
LIGHTING UNIT A W 1184	EA	1					
TOTAL			4805				

Columns 5, 6 and 10 should be left blank by the reporting carrier. Show on the first sheet of each valuation section a statement of the account numbers included in the report, a statement showing the changes in mileage, and a sworn statement as to the correctness of the report

EXHIBIT C Sheet 6 of 6

produce a set of summary cards which, when combined with summary cards from other valuation sections, will produce state, system or other summaries as required.

B. Partial Mechanization—BV 588 Summaries Only

A second road that was studied by the committee, which did not feel it had the volume to justify a full tabulating machine procedure, developed a very satisfactory application for the production of summaries only. This procedure routed an account completion report summary sheet through their tabulating machine department and punched a card for each account on each project, which was used to tabulate and print the valuation section, state and system summaries.

Conclusion

As stated at the opening of this report, the purpose of the committee was to determine if modern punched card equipment could be utilized to produce a BV 588 report. Our analysis of the various steps tells us that we can definitely state that the machine will perform the task and produce a satisfactory product that will be acceptable to the commission's bureau. We find that satisfactory results are obtained in case one only wishes to mechanize a portion of the procedure to avoid the time consuming task of combining valuation section summaries into state and system summaries. It is not possible nor desirable, within the scope of a study of this nature, to attempt to cover fully the tabulating machine field. In fact, as our report has indicated, even as the data was being developed improvements in the available equipment opened up additional possibilities for practical use.

Your committee, in submitting this report as information, desires to stress the fact that tabulating machine procedures are closely tied into volume, and that full mechanization of both the Completion Reports and the BV 588's is feasible only for the larger railroad systems. It is generally true that most railroads now have extensive tabulating machine bureaus, usually under the direction of an accounting officer. Any mechanization proposal for the engineering department only must be studied individually in the light of the conditions found on the individual carrier.

Report on Assignment 6

Valuation and Depreciation

(a) Current Developments in Connection with Regulatory Bodies and Courts

H. T. Bradley (chairman, subcommittee), R. B. Aldridge, S. H. Barnhart, M. A. Bryant, P. D. Coons, Spencer Danby, V. H. Doyle, W. S. Gates, Jr., M. M. Gerber, W. A. Godfrey, L. W. Howard, R. D. Igou, E. M. Killough, C. B. Martin, J. B. Mitchell, B. H. Moore, B. F. Nauert, C. F. Olson, W. C. Pauli, H. L. Restall, J. H. Roach, E. J. Rockefeller, W. F. Sanders, J. B. Styles.

Regulatory Bodies

The Interstate Commerce Commission's allocation of its appropriation for the valuation activities of the Bureau of Accounts Cost Finding and Valuation for the year beginning July 1, 1955, contains approximately $340,000. This compares with $370,000 for the previous year.

During the year the valuation forces of the Bureau were engaged principally in railroad and pipeline work, preparing many tentative and final valuations on an annual

basis for all pipeline companies subject to their jurisdiction. No tentative valuations were made for railroad companies.

During 1954, Class I carriers charged Account 459, Valuation Expenses, an amount of $771,008, contrasted with $763,222 for the year ended 1953.

As of October 1, 1955, the 131 line-haul Class I carriers were practically on a current basis in the filing of the 588 returns with the Bureau, with the following exceptions: 1 carrier not filing for the years 1949, 1950 and 1951; 6 for 1952, and 24 for 1953. Of the returns due December 31, 1955, 17 carriers have filed. The Valuation Order No. 3 Section of the Bureau is now 91 percent current in its field check of these returns.* The 588 returns enable the Bureau to carry into its continuous inventories and records the changes in property and their costs subsequent to the original valuation. These returns are made on an annual basis.

The Engineering Section of the Bureau, having completed revised inventories for the 131 Class I line-haul carriers through the year 1942, is engaged in bringing its inventories forward to later dates and, as of October 1, 1955, was approximately 81 percent* current (long form method). Since October 1, 1954, the engineering reports of 8 Class I carriers were brought to later dates, using the long form method. The work of the Order No. 3 Section in bringing summaries of original cost, other than land, to current dates is 94 percent* current; the summarization of original cost of land is 39 percent* current. The Land Section has completed 74 percent* of its work of adding additions and betterments to the latest appraisals which, except in a few cases, were as of 1945 or earlier.

In measuring progress on its railroad valuation work, the Bureau was not able to maintain a status quo in its program during the year, or even for the past five years, and it will be impossible with its limited personnel to keep abreast of its valuation work load, much less to make up arrears without increased forces. On October 1 the staff totaled 54 employees, of which 18 are in the Engineering Section, 25 in the Order No. 3 Section (15 office and 10 field), and 11 in the Land Section (7 office and 4 field).

Elements of Value as of January 1, 1954

The Bureau of Accounts, Cost Finding and Valuation prepared its estimates for the Class I carriers covering the standard elements of value as of January 1, 1954, and released them March 4, 1955. They were received in evidence as Exhibit 55–2 in Ex Parte 175 on September 26, 1955.

Report of Committee on Valuation, National Association of Railroad and Utilities Commissioners

In October the Committee on Valuation of the National Association of Railroad and Utilities Commissioners issued its 1955 annual report. This report consists of 10 pages of text, with an appendix of 12 pages of excerpts from state court and commission decisions in rate cases. Copies may be secured from the Office of the Secretary, NARUC, 7413 Post Office Building, P. O. Box 684, Washington 4, D. C., at 75 cents per copy.

The NARUC report reviews recent economic developments and their effect on regulatory problems, particularly the proper determination of utility valuations. It will be recalled that last year's report stated that 12 states had given recognition to fair value in determining a rate base. This year's report reviews later developments in these and other states and problems resulting from the impact of inflation on rate-making values.

The report also discusses the amendment of Section 167 of the Internal Revenue

* Based on 9,170,000 mile-years from basic valuation dates through 1954.

Code of 1954 by providing certain optional accelerated depreciation methods and their effect on rate base valuations. It also expresses some doubt as to whether accelerated depreciation results in a tax saving or in a tax deferral. The Federal Power Commission has adopted the latter view and "nearly all state regulatory commissions which have had cases involving amortization of emergency facilities for defense purposes have used normalized taxes in determining earnings and have not used the tax reduction to reduce rates or as a deduction from the rate base." The report further states that "Insofar as is known, no definite action has yet been taken by the federal regulatory agencies in connection with accounting for accelerated depreciation under the Internal Revenue Code of 1954."

The report also discusses the operating ratio method of determining earning deficiencies for truck, bus and tramway companies. This method contemplates the adjustment of rates to develop a satisfactory operating ratio without finding a rate base. Many commissions have been using this method, but so far it has not been sanctiond by the courts. The report concludes with the following summary:

> Prices have been quite stable since the end of 1952 in spite of the 1953–1954 inventory recession and the subequent recovery. Although there are some indications that we have been reaching a new high price plateau as some economists have been contending, there are other indications that we may be ready to start a new increased price spiral. In any event, the problems engendered by the 1940–1952 inflation will probably be with us for many years to come and will confront regulatory bodies in rate cases in the future as they have in the past.
>
> Accelerated depreciation for purposes of income tax computations will have to be considered in determining earnings requirements of utilities, although there are as yet no standards for determining how this matter should be handled from a rate determination or valuation standpoint.

Court Decisions

In the case of the Denver & Salt Lake Railway Company v. Commissioner of Internal Revenue, Docket 43783, 24 T. C. No. 78 . . . Dec. 21, 137, filed July 20, 1955, the Tax Court of the United States held that the commissioner erred in reducing the taxpayers basis for gain or loss by the deduction of depreciation allegedly allowed or allowable prior to January 1, 1943, on properties destroyed by fire. This decision, which involves sudden obsolescence claims, refers to the deduction of the 30 percent past accrued depreciation under the terms letters agreements made at the date of the changeover from retirement to depreciation accounting. In effect, the court held that nothing was said in the terms letter about using the 30 percent deduction in developing sudden obsolescence claims. A number of similar suits have been filed by other companies but have not yet been adjudicated.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

M. Friedman (chairman, subcommittee), S. H. Barnhart, B. Firestone, W. S. Gates, Jr., W. A. Godfrey, W. M. Hager, C. B. Martin, B. H. Moore, J. H. O'Brien, M. G. Pettis, J. H. Roach, F. A. Roberts, H. B. Sampson, J. R. Traylor, J. L. Willcox.

Since the last report of your committee, the following change has been made in the Interstate Commerce Commission Uniform System of Accounts for Railroad Companies:

By order dated Oct. 11, 1955, the ICC modified the provisions for condensed classifications of operating expense accounts for use by other than Class I carriers, effective Jan. 1, 1956. For the purposes of the condensed classification, the order divides the carriers into two general classes, designated as Class I and Class II. Class I includes all carriers having annual operating revenues of $3,000,000 or more, and Class II, all carriers having annual operating revenues less than $3,000,000. This supersedes the former classifications which were designated as Class I, Class II and Class III.

Beginning with the year 1956, the classification for accounting purposes is to be based on the average annual operating revenues for the 3-year period ending with the calendar year 1955. The order prescribes the method for the determination of the classification in cases where changes from Class I to Class II, or vice versa, become necessary because of changes in the annual operating revenues, the method for the initial classification of carriers that have been operated for a period less than 3 calendar years, and for newly organized carriers which commence operations for revenue subsequent to Jan. 1, 1956.

The condensed classification prescribed in the order is the same as to account numbers and descriptions of the accounts as the former condensed classification prescribed for Class III, small carriers, with the following exceptions:

Former Account Number 2259, Miscellaneous Operations, has been changed to Account Number 2258,

Account Number 2259, Operating Joint Miscellaneous Facilities–Dr., corresponding to Account Number 447 for large carriers, has been added,

Account Number 2260, Operating Joint Miscellaneous Facilities–Cr., corresponding to Account Number 448 for large carriers, has been added.

The effect of this order is that carriers having annual operating revenues between $1,000,000 and $3,000,000, which were formerly classified as Class I, and under that classification were required to use the primary operating expense accounts for large railroads, will, after Jan. 1, 1956 be classified as Class II and will be required to report as prescribed in the condensed classifications.

The Annual Report Form A shows in Schedule 515 rails laid in replacement, and in Schedule 516, rails laid in additional tracks and in new lines and extensions. The quantities of rail of the various pattern weights have been reported in gross tons. Beginning with the annual report for the year 1956, the quantities will be reported in short tons. There is no objection to this change in the Annual report, but should it be required that the valuation reports to the ICC reflect such change, a great deal of work would be required to convert previous valuation records which are stated in gross tons to short tons. The subcommittee has been assigned this subject for study and will report at a later date.

In the year 1948, the Bureau of Accounts and Cost Finding (now the Bureau of Accounts, Cost Finding and Valuation) of the ICC proposed the following subjects to the General Committee, Accounting Division of the Association of American Railroads, for consideration:

Subject No. 423—Proposed accounting order to require carriers to enter on their books of account the estimated original cost of their transportation property as developed by the Commission's Bureau of Valuation, in substitution for the presently recorded cost.

Subject No. 424—Proposed accounting order to substitute a requirement for depreciation accounting for ties, rail and other track material in lieu of the present replacement accounting.

Subject No. 425—Proposed accounting order to reduce from $500 to $100 the cost of additions and betterments which may be charged direct to operating expenses under the so-called minimum rule.

Subject No. 426—Proposed accounting order to require railroads to set up in their accounts the amount of unrecorded depreciation on depreciable road property.

The revisions of the Uniform System of Accounts to reflect the above changes would have a decidedly marked effect on the investment accounting for road property changes, and the AAR committee assigned the subjects to a special committee for study. The special committee submitted a report opposing adoption of the proposed accounting orders and recommended that they be withdrawn by the ICC Bureau. The report was approved by the general committee and transmitted to the director of the ICC Bureau on April 27, 1950. The subjects have been continued on the docket of the general committee from year to year for the purpose of noting developments and were finally dropped from the docket at the meeting of the Railway Accounting Officers in 1955.

This report is presented as information only.

Report of Committee 1—Roadway and Ballast

B. H. Crosland,
Chairman,

A. P. Crosley,
Vice Chairman,
G. B. Harris, *Secretary,*
W. T. Adams
E. R. Anderson
R. A. Anderson
E. W. Bauman
R. H. Beeder
F. N. Beighley
C. R. Bergman
D. W. Blair
L. H. Bond
J. A. Bunjer
J. E. Chubb
H. W. Clarke
B. S. Converse
M. G. Counter
M. W. Cox
J. P. Datesman
M. B. Davis
T. F. deCapiteau
L. J. Deno
W. G. Dyer
C. E. Dysart
W. P. Eshbaugh
J. B. Farris
J. G. Gilley
A. T. Goldbeck
R. A. Gravelle
F. W. Hillman (E)
H. G. Johnson
L. V. Johnson
H. S. Leard
H. W. Legro (E)
R. R. Manion
G. D. Mayor
E. W. McCuskey
F. H. McGuigan
Paul McKay
G. W. Miller
F. R. Naylor
J. A. Noble
J. W. Poulter
G. W. Payne (E)
J. W. Purdy
L. E. Rundell
K. W. Schoeneberg
A. W. Schroeder
J. R. Scofield
L. D. Shelkey
L. R. Shellenbarger
H. F. Smith
R. M. Smith
G. S. Sowers
W. O. Trieschman
C. D. Turley*
Stanton Walker
C. E. Webb
A. J. Wegmann
Charles Weiss
A. A. Winter
J. C. Woods
J. D. Worthing
W. L. Young

Committee

(E) Member Emeritus.
* Deceased.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report (See reports on Assignments 4 and 6).

2. Physical properties of earth materials.
   (a) Roadbed. Load capacity. Relation to ballast. Allowable pressures.
   (b) Structural foundation beds, collaborating with Committees 6 and 8.

   No report.

3. Natural waterways: Prevention of erosion.

   No report.

4. Culverts:
   (a) Conditions requiring head walls, wing walls, inverts and aprons, and requisite therefor.

   No report.
   (b) Specifications for high-pressure gas lines.
   Presents Manual recommendations with respect to specifications for pipe line crossings under railway tracks ..... page 645

(c) Methods for installing culverts inside of existing culverts.

No report.

6. Roadway: Formation and protection:

(a) Roadbed stabilization.

Progress report, presented as information ..... page 648

Part 1—Relocation of railroad embankment ..... page 649

Part 2—Stabilization by electro-osmosis ..... page 658

(b) Construction and protection of roadbed across reservoir areas; specifications.

Final report, submitting material for adoption and inclusion in the Manual page 648

7. Tunnels:

(a) Ventilation; changes necessary for operation of diesel power.

Progress report, presented as information ..... page 660

(b) Clearance; methods used to increase, collaborating with Committee 28.

No report.

8. Fences:

Critical review of all methods of preventing snow drifts.

No report.

9. Reflectorized roadway signs, collaborating with Committee 9 and the Signal Section, AAR.

No report.

10. Ballast:

(a) Tests.

Progress report, presented as information ..... page 661

(b) Ballasting practices.

No report.

(c) Special types of ballast.

No report.

(d) Specifications for sub-ballast.

No report.

11. Chemical control of vegetation, collaborating with Signal Section and Communication Section, AAR.

Part 1—Fifth annual report on AAR cooperative weed control project .... page 662

Part 2—Chemical control of vegetation—1955 AAR report ..... page 670

THE COMMITTEE ON ROADWAY AND BALLAST,
B. H. CROSLAND, *Chairman*.

Report on Assignment 4 (b)

Specifications for High-Pressure Gas Lines

G. B. Harris (chairman, subcommittee), W. T. Adams, H. W. Clarke, B. S. Converse, T. F. DeCapiteau, J. W. Purdy.

Page 1–5–1 to
1–7–7 of the Manual

SPECIFICATIONS FOR PIPE LINE CROSSINGS UNDER RAILWAY TRACKS

In 1954, when considering the Specifications for Pipe Line Crossings Under Railway Tracks, the Association approved for publication in the Manual, Sec. A of these specifications, for flammable substances. In 1955, the committee presented as information, for criticism, a revised Sec. B of these specifications, for non-flammable substances. Sec. B—For Non-Flammable Substances, with further revisions, is now presented in the following, with the recommendation that it be approved for publication in the Manual, replacing present Sec. B. The committee also recommends the reapproval, without change, of Sec. A—For Flammable Substances.

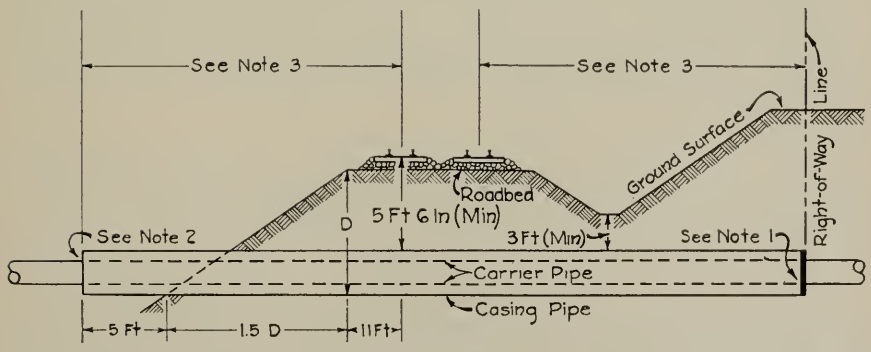
B. FOR NON-FLAMMABLE SUBSTANCES

1. Scope

Pipe lines included under these specifications are those installed to carry steam, water or any non-flammable substance which, from its nature or pressure, might cause damage if escaping on or in the vicinity of railway property.

2. Installation

Pipe lines under railway tracks and across railway right-of-way shall be encased in a larger pipe or conduit called the casing pipe, in accordance with the specifications and as indicated in Fig. 4. Casing pipe shall be installed under tracks by boring or jack-



NOTES: 1. Ends of casing, when below ground, shall be suitably protected against entrance of foreign material.
2. Ends of casing, when above ground surface and above high water level, may be left open where drainage is available.
3. Casing pipe shall extend a minimum distance of 11 ft plus 5 ft plus 1.5 D measured at right angles from center line of outside track (Where D equals the depth of bottom of casing below subgrade), or to railway right-of-way, whichever is greater

Fig. 4.

ing, if practicable. Any replacement of a carrier pipe or casing pipe shall be considered a new installation, subject to the requirements of these specifications.

3. Carrier Pipe

Carrier line pipe and joints inside of casing under railway tracks and right-of-way shall be of approved construction satisfactory to the railway company. Joints for carrier line pipe operating under pressure shall be of mechanical or welded type. Pipe shall be laid with slack (no tension) in the line, or with expansion joint near the point of railway crossing.

4. Casing Pipe

Casing pipe and joints shall be of leakproof construction, capable of withstanding railway loading.

Wall Thickness For Steel* Casing Pipe For E 72 Loading (Including Impact)

Minimum Thickness Inches	*Diameter of Pipe Inches*
1/4	6, 8, 10, 12, 14 and 16
5/16	18 and 20
3/8	22 and 24
7/16	26 and 28
1/2	30, 32 and 34
9/16	36 and 38
5/8	40 and 42

* Thickness is for steel pipe having a minimum yield strength of 35,000 psi. Adjust thickness as necessary for other grades of pipe, except that thickness of pipe shall not be less than 1/4 in.

Class 150 cast iron pipe may be used for 12 in and under and Class 250 shall be used for over 12 in, provided the method of installation is by open trench and prior approval has been secured from the chief engineer of the railway company.

The inside diameter of the casing pipe shall be at least 2 in greater than the largest outside diameter of the carrier pipe, joints or couplings, for carrier pipe less than 6 in. in diameter; and at least 4 in greater for carrier pipe 6 in and over in diameter. It shall, in all cases, be great enough to allow the carrier pipe to be removed subsequently without disturbing the casing pipe or roadbed.

Casing pipe shall be so constructed as to prevent leakage of any matter from the casing or conduit throughout its length under track and railway right-of-way, except at ends of casing or conduit where ends are left open. Casing shall be so installed as to prevent the formation of a waterway under the railway and with an even bearing throughout its length, and shall slope to one end.

For pressures under 100 psi in the carrier pipe, the casing pipe may be reinforced concrete pipe conforming to the AREA Specifications for Reinforced Concrete Culvert Pipe (Table 2 for extra strength pipe), Part 10, Chapter 8, or bituminous coated corrugated metal pipe conforming to the AREA specification for such pipe, Part 4, this Chapter.

5. Protection Against Corrosion

Carrier pipe, when of steel material, shall receive externally the same protective coating which is applied to the carrier pipe adjacent to the crossing, except that in no case shall the protective coating be less than a coal-tar primer coat, followed by a single

application of hot coal-tar enamel $\frac{3}{32}$ in thick $\pm \frac{1}{32}$ in, plus a bonded 15-lb asbestos felt wrap, or in lieu of the above, the coating shall be an approved substitute equal to this combination protective coating.

Before installation, electrical detection methods shall be used to locate flaws or breaks in the coating. All damaged or broken coatings shall be repaired or replaced. Installation shall be made in such manner that the protective coating of the carrier pipe is undamaged.

Where adjacent carrier pipe is cathodically protected, this protection shall be extended to the casing pipe in addition to the protective coatings. Where such protection is provided, the railway company shall be notified and suitable test made to insure that other railway structures and facilities are adequately protected from the cathodic current in accordance with the recommendations of Report of Correlating Committee on Cathodic Protection, published in July 1951 by the National Association of Corrosion Engineers.

6. Protection at Ends of Casing

Where the ends of the casing are below ground they shall be suitably protected against the entrance of foreign material, but shall not be tightly sealed. Where the ends of the casing are at or above ground surface and above high water level they may be left open, provided drainage is afforded in such manner that leakage will be conducted away from railway tracks or structures.

7. Depth of Casing

The depth from base of railway rail to top of casing directly under the track shall not be less than 5½ ft. If the end of the casing pipe is below ground, so as to obscure its position, the depth from surface of right-of-way and from bottom of ditches to top of casing shall not be less than 3 ft.

8. Length of Casing

Casing shall extend each side from the center line of the outside track, measured at right angles, a minimum distance of 11 ft + 5 ft + 1.5 D (where D equals the depth of the bottom of the casing below subgrade), and shall extend to the railway property line if this distance exceeds the minimum required by the foregoing formula (see Fig. 4). If additional tracks are constructed in the future, the casing shall be correspondingly extended.

9. Shut-Off Valves

Where substances are transmitted under pressure an emergency shut-off valve shall be installed within effective distance at the pressure side of the crossing, outside of railway right-of-way.

10. Gravity Sewer Crossings

Casing pipe will be required where the carrier pipe is of a material or grade incapable of withstandnig railway loading, in which event the same requirements as specified in Art. 4 will govern.

11. Location

Pipe lines shall be located, where practicable, to cross tracks at approximately right angles thereto, and shall not be placed within a culvert or under railway bridges, except in public thoroughfares when mutually agreed to by the railway company and the owner

of the pipe line. Crossings, where possible, shall be located where the ground surface slopes downward away from the railway. Longitudinal occupancy of railway right-of-way is highly objectionable and must be avoided where possible.

12. Approval of Plans

Plans containing all pertinent details for the proposed crossing shall be submitted to and meet the approval of the chief engineer of the railway company before installation is begun. Plans shall be drawn to scale, showing the angle of crossing, location of valves, railway survey station, right-of-way lines and general layout of tracks and railway facilities near the point of crossing. Plans should also show a cross section along pipe line, from field survey, showing pipes in relation to actual profile of ground and tracks, and if open cut or tunneling is necessary, shall include details of sheeting and method of supporting tracks or driving tunnel.

The execution of the work on railway right-of-way, including the supporting of track, shall be subject to the inspection and direction of the chief engineer of the railway company.

In addition to the above, plans should contain the following data:

	Carrier Pipe	*Casing Pipe*
Contents to be handled	.....	.....
Diameter—Inside and outside	.....	.....
Material and type of pipe	.....	.....
Specification and grade	.....	.....
Weight per lin ft	.....	.....
Actual working pressure	.....	.....
Test pressure	.....	.....
Type of joint	.....	.....
Coating	.....	.....
Method of installation	.....	.....
Protection at ends of casing:		
Both ends ..... One end ..... Type		
Bury: Base of rail to top of casing ..... ft ..... in		
Bury: (Not beneath tracks) ..... ft ..... in		
Bury: (Roadway ditches) ..... ft ..... in		
Cathodic protection		

Report on Assignment 6

Roadway: Formation and Protection

(a) Roadbed stabilization

(b) Construction and protection of roadbed across reservoir areas; specifications

L. D. Shelkey (chairman, subcommittee), F. N. Beighley, M. G. Counter, W. P. Eshbaugh, R. A. Gravelle, W. T. Johnston, F. R. Naylor, A. W. Schroeder, H. F. Smith, W. L. Young.

Your committee reports this year on both of its assignments (a) and (b). The report on Assignment (a) is submitted in two parts, designated as Part 1 and Part 2.

Part 1 presents, as information, construction data for the successful stabilization of a relocated railroad embankment by the installation of a system of vertical sand drains and by subjecting it to an overload of fill for some months.

Part 2 is a report on soil stabilization by the electro-osmosis process. It is presented as information with the thought that it may serve to suggest the desirability of an actual, initial installation, in a railroad fill, for experimental purposes.

Parts 1 and 2 were prepared by Dr. R. B. Peck, research professor of foundation engineering at the University of Illinois. This work, under committee sponsorship, is part of the cooperative investigation of the Engineering Division and the Engineering Experiment Station of the University of Illinois, under the direction of G. M. Magee, director of engineering research, AAR, and Dr. Peck.

The report on Assignment 6(b), Construction and Protection of Roadbed Across Reservoir Areas, was published last year in the Proceedings, Vol. 56, pages 706–711, with the statement that it would be proposed for adoption and inclusion in the Manual in 1956. It is now recommended that this material (not reproduced herein), be approved and that the assignment be discontinued. It is planned to insert the material in Chapter 1 of the Manual as a new document immediately following page 1–1–36.

Report on Assignment 6 (a)

Part 1

Relocation of Railroad Embankment O'Hare Field, Chicago

By Ralph B. Peck
Research Professor of Foundation Engineering, University of Illinois

General

The expansion of O'Hare airfield, west of Chicago, in 1951 and 1952 necessitated the relocation of the tracks of the Milwaukee and the Northwestern railroads to a line along the western edge of the airport. The layout of the facilities was such that a considerable portion of the relocation had to be established over a swamp underlain by an extensive peat deposit. It was realized that construction in this area would be expensive because the building of fills over such deposits has often been accompanied by extensive slides and subsidences during construction, and by large and irregular settlements, usually persisting for decades. Since the existing tracks were stable, it was obligatory to furnish new facilities of at least equal stability.

Subsoil Conditions

A profile showing the railroad grade and the peat deposit is given in Fig. 1. The peat deposit extended from station 209 to 227 of the railroad, and it had a maximum depth of 20 ft near station 222. Several auger borings were made to determine the extent of the deposit and 2-in samples were obtained in thin-walled tubes from 2 wash borings. The samples of peat were so soft that satisfactory unconfined compression tests could not be performed. The water contents and Atterberg limits were determined and are plotted in Fig. 2. The consolidation characteristics are given in Fig. 3. The peat was underlain by medium stiff clay with an unconfined compressive strength of about 1.5 tons per sq ft.

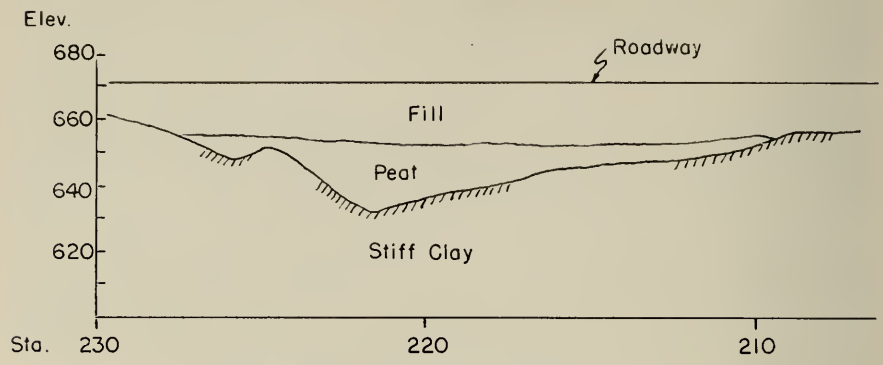


Fig. 1—Soil profile, O'Hare field.

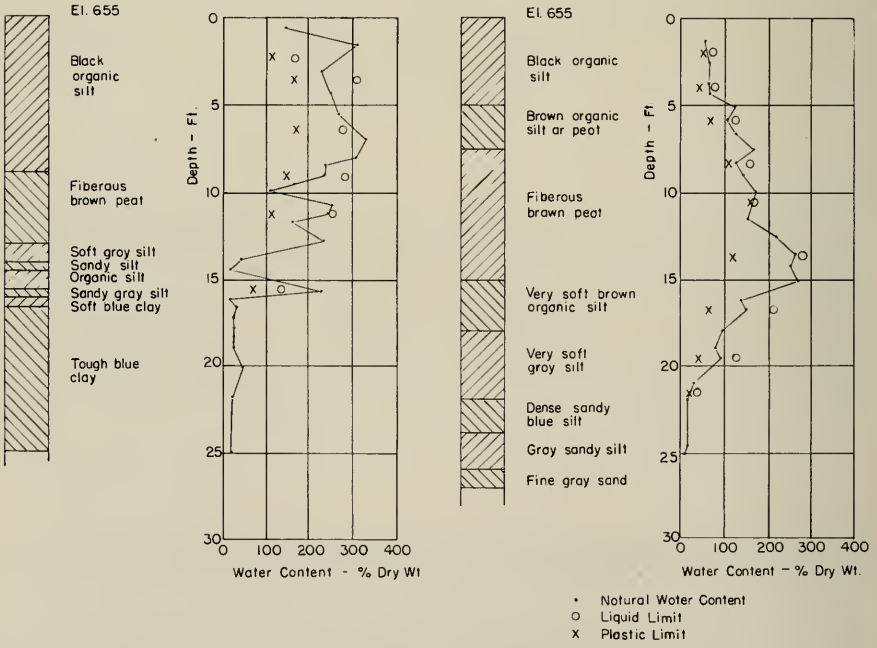
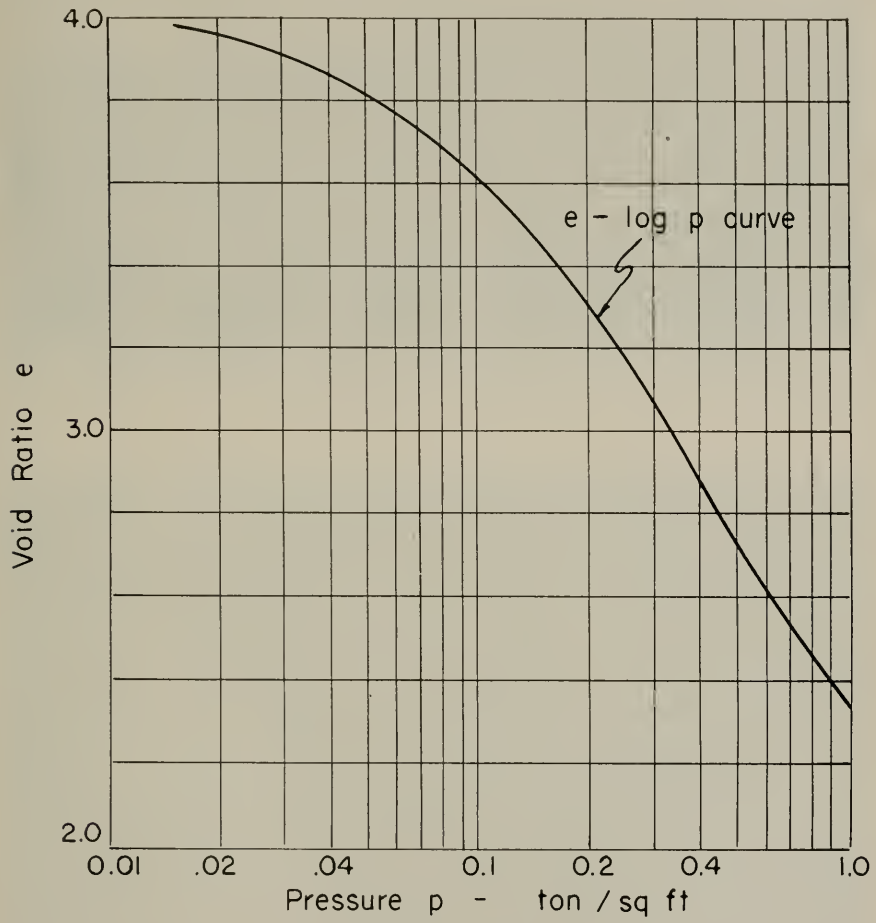


Fig. 2—Character of swamp deposit, O'Hare field.



Coef. of Consolidation $C_v = 3 \times 10^{-4}$ cm^2 / sec

Coef. of Permeability $K = 7 \times 10^{-8}$ cm / sec

(Values at e = 2.6)

Fig. 3—Consolidation test data for peat, railroad relocation, O'Hare field.

Fig. 4—Looking south over sand drain area, railroad relocation, O'Hare field.

Choice of Method of Construction

An agreement was reached between the railroads and the City of Chicago that no tracks would be relocated over unstable material. The character of the peat was such that any attempt to construct the roadbed would have resulted in instability and excessive settlements unless the peat were either removed or stabilized. This fact was demonstrated by the long history of repeated fillings and uneven settlement of the county road adjacent to the relocation (see Fig. 4).

Since the combined rights-of-way had a width of 200 ft, removal of the peat by excavation would have been extremely costly, especially in view of the flat slopes that the swampy material could be expected to assume. Displacement of the peat by blasting or by filling was considered inadvisable because of the virtual certainty of trapping extensive bodies of soft material beneath the fill. Moreover, a high-pressure gas line was located between the highway and the railroad right-of-way. Therefore, it was decided to stabilize the peat by the installation of a system of vertical sand drains and subjecting it for some months to an overload of fill. The plans called for a surcharge of 10 ft to remain in place until settlements had become insignificant, after which the surcharge was to be removed and the roadbed constructed. The sand drains were expected to shorten the time required for consolidation, and thus to permit applying the surcharge at a reasonable rate without failure of the underlying materials, as well as to accelerate the settlement under the surcharge.

The principle of the sand-drain method is illustrated in Fig. 5. The soft deposit is weak and very compressible, but since it is saturated it cannot settle and compress except as water is squeezed from the pores. Before a particle of water at a point such as (a) can leave the deposit, if no vertical drains are present, it must travel upward through the entire deposit to the pervious blanket at the top. This may require considerable time. However, if several vertical drains are inserted and filled with pervious material, the water at point (a) has only to go the relatively short horizontal distance to the nearest drain where it finds ready exit through the drainage system. Thus, the process of drainage is greatly accelerated. In favorable situations, the drainage may

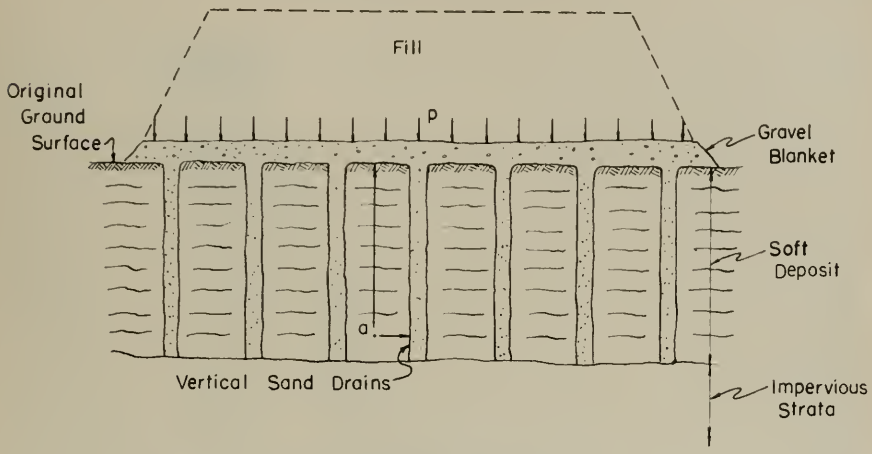


Fig. 5—Sand drain method.

Fig. 6—Flap valve on end of pipe for driving sand wells.

become so rapid that the excess water is squeezed out almost as rapidly as the overlying fill (p) is added. The settlement then keeps pace with the added load, and at the same time the strength of the soil is increased because of the reduction in water content. If the fill load (p) is temporarily greater than the permanent load to be applied to the soft soil, the settlement under the permanent load should be negligible.

Fig. 7—Hopper feeding sand into driven pipe.

History of Construction

Construction began with the placement of 3 ft of granular material which served as a combined working platform and drainage blanket. The sand drains, 20 in. in diameter, were then installed on 12.5-ft centers by a modified crawler-mounted pile-driving rig. The procedure consisted of driving a pipe through the blanket and the peat

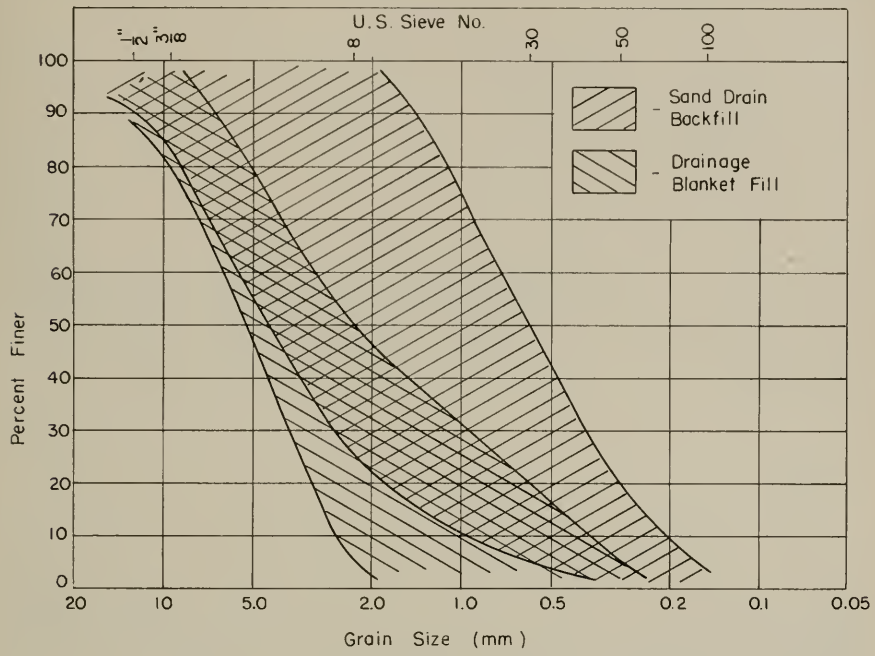


Fig. 8.

to the stiff clay. The pipe was closed at the bottom by a flap valve, Fig. 6. While it was being driven, sand was fed into the pipe by a hopper, shown in Fig. 7. When the bottom was reached and the pipe was fully charged, the top of the pipe was closed and air under pressure was introduced into the pipe. The flap valve opened and the sand was discharged as the pipe was pulled. The air pressure kept the hole from collapsing as the sand entered during withdrawal of the pipe, and also decreased the required pulling load. The operation was rapid; about 3 min were required for driving, extracting, and moving to the next position. The grain-size characteristics of the blanket and drain materials are shown in Fig. 8.

The embankment and surcharge slopes were established as shown in Fig. 9, with a drainage ditch to remove the water squeezed from the peat into the drainage blanket through the drains. The permanent part of the embankment, plus an allowance for settlement, was of compacted select material. The remainder, used temporarily for weight only, was of uncompacted clay. The rate of filling was specified not to exceed 4 ft per week. On the basis of the consolidation-test data, a computation of the allowance for settlement was made. The maximum value was found to be about 4 ft.

Filling was begun in March 1952. When the fill was built up to about 8 ft, several slips occurred in which the outer 50 ft of fill subsided, in one instance as much as 3 ft, and the bottom of the ditch heaved. It was determined that the ditch and the adjacent steep slope produced a tendency toward local instability. The ditch was replaced by a pipe and backfilled, and the slope was flattened and extended over the backfill at about 1:3. This treatment and a reduction in rate of filling to not more than 2 ft per week

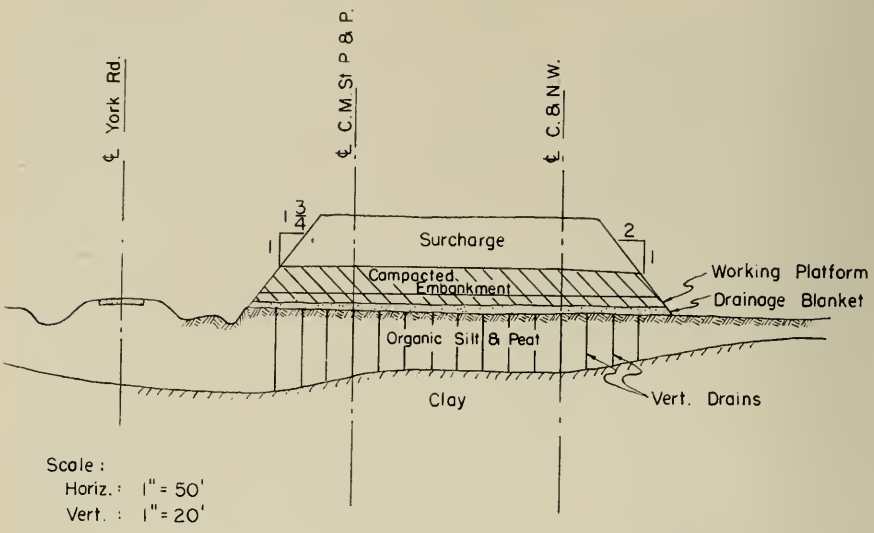


Fig. 9—Cross section, station 218, O'Hare field.

eliminated most similar occurrences. In a few instances counterweights, about 3 ft high, alongside the embankments were added when cracks appeared in the top of the fill. By these procedures the fill was completed to a height of 15 ft in September.

Settlements

Settlement platforms were established at 14 locations and measurements were made regularly. Representative results are shown in Fig. 10. The surcharge was removed in the summer of 1953, whereupon a slight rebound or almost complete cessation of settlement occurred. The amount of settlement agreed well with that predicted, but the rate was slower, as demonstrated by the necessity of reducing the rate of application of the surcharge.

Operation over the new lines began in 1954. In June 1955 the profile, of the Milwaukee tracks was determined before the first resurfacing. The measurements indicated a gentle sag over the deepest part of the peat bog amounting to a maximum of 0.39 ft. No local settlements or unusual vibrations have been noted and the stabilization treatment is considered successful.

Cost

The stabilization of the area, having a length of 2000 ft and a width of 200 ft, was accomplished for a cost of $509,000, or approximately $4 per cu yd. The cost of performing the work by excavation and replacement is indeterminate because of uncertainty regarding the slopes upon which the cuts would have stood. It is probable that the cost would have exceeded $600,000, and the hazards of construction would have been much greater.

Fig. 10—Swamp deposit settlement, O'Hare field.

Part 2

Stabilization By Electro-Osmosis

By Ralph B. Peck

Research Professor of Foundation Engineering, University of Illinois

Some 25 years ago, L. Casagrande found that, by passing an electric current through a sample of clay, water could be made to flow through the clay and that, in addition, parts of the clay sample consolidated and grew stronger. Continued studies since that time have led to an understanding of the principles involved, and to numerous practical applications.

It has been found that if an electric potential is applied to a saturated soil, water moves through the pores from the anode (+) to the cathode (—). If the cathode consists of a wellpoint, the water that flows into it can be removed by pumping and the soil can thereby be drained. Moreover, in contrast to the laws of permeability that apply to purely hydraulic systems, the laws that govern the flow under electric potential indicate that the rate of flow is independent of the size of the pores in the soil. That is, the permeability of a clay soil to electro-osmotic flow is no less than that of silts or even of sands. Since the fine-grained soils are practically impervious to gravity flow they are normally considered undrainable, but in fact they can be drained satisfactorily by electro-osmotic drainage.

For practical purposes, most soils have a coefficient of electro-osmotic permeability of about 0.5×10^{-4} cm/sec for a potential gradient of 1 v per cm. A tight clay may have a hydraulic coefficient of permeability of 10^{-8} cm/sec. For such a clay, the hydraulic gradient which would cause the same rate of flow as a potential gradient of 1 v per cm would be 5000 ft per ft, or a head of about 1 mile per foot of distance. Thus, the potentialities of electro-osmotic drainage are apparent.

In practice, an installation usually consists of a series of vertical pipes driven into the mass to be stabilized; these pipes are perforated and serve as cathodes to which the water is driven and from which it is collected. In addition, intermediate electrodes, usually consisting of solid rods, are driven to serve as anodes. The spacing varies considerably, depending on the character of the project and the nature of the soil; usually it lies between the range 10 to 17 ft. The potential is supplied by direct-current generators, usually at about 90 v, although voltages from 30 to 180 have been used. In some soils, aluminum anodes are advantangeous because they promote certain chemical changes that strengthen the soil.

The use of electro-osmosis in the United States is patented and licensed; the licensees operate in close cooperation with Dr. L. Casagrande, the inventor of the procedure.

It is notable that the first full-scale application of the process was on railroad work. In 1939, a cut in wet clayey silt in Germany proved impossible to drain by wellpoints. A 300-ft test section for electro-osmotic drainage was installed with cathodes and anodes alternately spaced at 15-ft intervals on each side of the excavation. Within a few hours after a potential of 180 volts was applied, excavation in the unstable bottom could be resumed. The rest of the cut was then successfully treated, at a consumption of energy of 1 kwh per cu yd of excavation.

In Scotland, after a railway fill 50 ft high had been washed out by a flood and replaced with very soft material as an emergency measure, the soft material was successfully drained and strengthened by 1 row of electrodes spaced at 11-ft intervals, subjected to a potential of 90 v for 6 months, with an energy consumption of 61,000

kwh. After stabilization it was possible to tunnel beneath the fill for a culvert without special precautions.

No application to railroad work has yet been made in the United States or Canada, but several large projects of other kinds have been carried out. To obtain an indication of the cost of stabilizing a typical soft fill, a study was made of an embankment near Terre Haute, Ind., and estimates were prepared by a representative of the licensee. These data, which follow, indicate the nature and cost of the work and may serve to suggest the desirability of an actual installation for experimental purposes.

For each estimate the following is assumed: (Fill is approximately 220 ft long 50 ft high)

1. Labor (railroad men) at $1.50 per hr.
2. Transportation to the job site by the railroads. Equipment to be f.o.b. Hammond, Ind., or New York, N. Y.
3. Routine daily inspection of the system after it is in operation to service the generators and check the operation of the system (about 4 hr work every day).
4. Fuel delivery to the job site by the fuel suppliers.
5. An average clay soil.
6. Supervisory personnel to be furnished by the licensee.
7. All materials excepting air compressor, sheeting hammer and hose to be furnished by the licensee.

Cost Estimate for Using Electro-Osmosis for Stabilizing a Clay Fill Against a Slope Failure That Extends Through the Toe of the Fill

Item 1			
Install and remove E-O system			
1000 man-hr. @ $1.50/hr (railroad men)	$1500.00		
Operation			
90 days—assumed one man visits the job and spends ½ day there			
$\frac{90}{2}$ = 45 days			
45 day x 8 hr x $2.50 =	900.00		
			$ 2400.00
Item 2			
Taxes, insurance, S. S., etc.			
Say 15 percent of Item 1 $2400.00			360.00
Item 3			
Equipment—Rental and sale anodes and cathodes 4500′ A1 pipe w/900 cut and threads @ $0.64 per ft	$2880.00		
800 A1 couplings @ $0.62	496.00		
Wire—			
2000 ft 4/0 w/leads and fittings @ $0.35/ft/month x 3 month	2100.00		
Diesel generator—w/panel board @ $800.00/month x 3 month	2400.00		
			$ 7876.00
Item 4			
Air compressor and sheeting hammer (railroads)	$ 300.00		
Small tools	50.00		
Instruments	50.00		
Shanty	100.00		
Fuel—			
100 gal diesel oil @ $0.15/gal = $15.00 a day x 90 days	1350.00		
3 qt motor oil @ $0.40/qt = $1.20 x 90	108.00		
Filters, etc., $1.00/day x 90 days =	90.00		
Freight 20,000 lb one way—8,000 lb one way	600.00	(assumed)	
			$ 2648.00
Item 5 (Overhead)			
Supervisor			
20 days @ $42.00 per day	$ 840.00		
Soils engineer			
3 days @ $75.00/day	225.00		
Laboratory analysis (Casagrande)	200.00		
Traveling expenses—			
Supervisor	150.00		
Soils engineer	150.00		
			$ 1565.00
			$14849.00

RECAPITULATION

Item	
1	$2400.00
2	360.00
3	7876.00
4	2648.00
5	1565.00
Total	$14849.00

Report on Assignment 7

Tunnels

(a) Ventilation; changes necessary for operation of diesel power.
(b) Clearance; methods used to increase, collaborating with Committee 28.

J. A. Bunjer (chairman, subcommittee), E. R. Anderson, D. W. Blair, W. G. Dyer, G. W. Miller, Charles Weiss.

Your committee submits, as information, progress report on Assignment (a) only.

(a) Ventilation; Changes Necessary for Operation of Diesel Power

In order to compare the problems of ventilating a tunnel for steam-power operation with the ventilation problems involved for diesel operation, and thereby establish a basis for the study of this assignment, the committee is endeavoring to assemble and develop information regarding ventilation of railroad tunnels for both diesel and steam power from the surprisingly meager data available.

A review of reports on both theoretical determination and on results of field studies of tunnel ventilation indicates that there are so many factors affecting the design that the solution of each case can only be determined after consideration of the tunnel physical characteristics, bore area in relation to train area, train speed, train frequency and direction, and all conditions of air pressure at portals and at various critical points in the tunnel. However, the following rather general conclusions developed by the various reports seem to be particularly informative:

Studies of present or contemplated ventilation systems of some tunnels indicate that natural ventilation obtained without the use of fans might be sufficient if diesel locomotives were to replace the present coal-burning steam power. In other tunnels the accumulation of diesel exhaust gases under heavy traffic is such that, without forced ventilation, severely noxious conditions would result and ventilation equipment is considered necessary.

The first assumption of tunnel ventilation theory is that trains are seldom bothered with the smoke or fumes from their own locomotives. If the tunnel is clear with the entrance of the train, ventilation is usually satisfactory. In this regard, it can be stated that if a train were to enter the average tunnel when the tunnel was filled with gases, no fan system made within any reasonable limit of power input could relieve the crew until the train had traversed most of the tunnel length.

It is, therefore, the desire to have or create ventilation facilities which will clear the tunnel in the shortest economical space of time between trains. For forced ventilation systems, it is apparent from fan horse-power and air-volume studies that there is a minimum time for clearing the tunnel, below which it is not economical to go, because of high power costs. From investigations undertaken, forced ventilation which is effective for all conditions of air pressure cannot be secured with only a vertical shaft blower system, for with certain pressure differences at portals, undesirable long ventilation times

result, and in extreme cases the gases in one part of the tunnel stagnate and cannot be removed by the vertical shaft ventilation.

It appears that the principal resistance to any blowing operation is imparted by the train rather than the tunnel walls, and that it is desirable to eliminate as much of this train "piston effect" as possible by blowing behind trains instead of against them. It usually is not feasible to blow at such a rate that products of combustion will be carried ahead of the engine, but it does prove practicable and economical to provide fans designed to blow behind trains at a rate less than train speed. This procedure is based on the theory that the ventilation provided by the train itself in a clean tunnel is sufficiently great so that artificial ventilation may actually be diminished, and that as long as train speed is in excess of air velocity in the tunnel, there will be a flow of air from front to rear of train sufficient to provide minimum discomfort to train crews and none to passengers.

Report on Assignment 10

Ballast

(a) Tests
(b) Ballasting practices
(c) Special types of ballast
(d) Specifications for sub-ballast

R. H. Beeder (chairman, subcommittee), E. W. Bauman, J. P. Datesman, A. T. Goldbeck, E. W. McCuskey, L. E. Rundell, R. M. Smith, C. D. Turley, Stanton Walker.

Your committee submits, as information, report under Assignment (a) Tests. The other assignments are being studied actively but sufficient data have not been received for report at this time.

Report on Assignment 10 (a)

Tests

Third Progress Report on Research Project on Ballasts

This is the third progress report on oscillator ballast tests now in progress at the Association of American Railroads Research Center. These tests were described in detail in the Proceedings, Vol. 54, 1953, page 1140, and the Proceedings, Vol. 56, 1955, page 717.

Tests have now been completed on a number of ballast materials. These materials include slag, chat, gravel from two sources, and several crushed rock ballasts, including trap rock and three limestones from various sources.

Work is being continued on these tests and it is expected that within a year sufficient information will be available to present and discuss data and to draw preliminary conclusions.

Report on Assignment 11

Chemical Control of Vegetation

Collaborating with Signal Section and Communications Section, AAR

C. E. Webb (chairman, subcommittee), C. R. Bergman, M. W. Cox, L. J. Deno, H. S. Leard, G. D. Mayor, W. O. Trieschman, A. A. Winter.

The report on this amendment is submitted as information. It consists of two parts. Part 1 is a resumé of the research being conducted at Iowa State College, University of Florida, and Montana State College as a cooperative project between these institutions and the Engineering Division, AAR. The report has been prepared by the staff members of the colleges.

Part 2 is a report of the field observations made by the AAR research staff on the results of chemical applications. This work has been performed under the general direction of G. M. Magee, director of engineering research, and under the direct supervision of Rockwell Smith, research engineer roadway. The report has been prepared by C. G. Parris, agronomist, and Rockwell Smith.

As noted in a previous report, Proceedings, Vol. 56, 1955, pages 724–731, the United States and Canada have been divided into seven regions of somewhat comparable climate and vegetation. This division has been continued this year and each region is reported separately as to type, rate and time of application, and results.

Part 1

Fifth Annual Report on AAR Cooperative Weed Control Project[1]

By W. E. Loomis, E. G. Rodgers, L. O. Baker, and R. H. Schieferstein[2]

The season of 1955 completed a total of 12 years of research on control of vegetation on roadbeds by the three contracting institutions. Work has been under way for five years in Iowa, four in Florida, and three in Montana. Some 4000 individual tests of herbicides, combinations of herbicides, rates, season, etc., have been run under a wide variety of climatic, soil, ballast, seasonal, and vegetational conditions.

It might be assumed that these tests would have solved all the problems of roadbed vegetation control in the three areas. They do give many indications of what may be expected in future programs but two points are still troublesome: resistant plants, as roses, milkweeds, and horsetails in Iowa, and costs. An annual application of 50 lb of CMU and 500 lb of sodium chlorate will give generally satisfactory weed control on a mile of track—at a cost of about $200. Most railroads are unable or unwilling to spend this much money on weed control; consequently, the major emphasis in the work has been directed toward the development of programs that will control vegetation at an average annual cost of less than $100 per mile.

[1] This is a report of a cooperative project, supported in part by the Association of American Railroads, between the Association, the Iowa and Montana Agricultural Experiment Stations, and the Department of Agronomy, University of Florida, with the cooperation of local railroads in the three areas.

[2] Respectively: professor of plant physiology, Iowa Agriculture Experiment Station, Ames, Iowa; professor of agronomy, University of Florida, Gainesville, Fla.; assistant agronomist, Montana Agricultural Experiment Station, Bozeman, Mont.; and research associate, Iowa Agricultural Experiment Station.

One way of reducing costs in many situations is to use mixed sprays and to respray rather than to attempt to hold the area weed-free for long periods. A single application of CMU gave good control of weeds, other than horsetail, on dry, stoney soil in Montana over a period of 3 years, when used at a rate of 80 to 160 lb per mile. In Ames, however, control was less than 50 percent in the second year with 80 lb per mile, or 40 lb per acre. Poor control is due to resistant perennials and annuals or to annuals that develop on the track after the chemical is leached from the upper layers of soil or ballast. Resistant perennials require treatment with chemicals to which they are more susceptible, and annuals can be controlled better and much more economically by respraying with aromatic oils than by attempting to get long-time effects with any chemicals now available.

The results to date indicate rather definitely that it is uneconomical to attempt general weed control for more than one season with a single treatment, and that two treatments per season with less expensive chemicals or lighter rates may at times be still more economical. These statements must, however, be combined with a third. A clean track is easiest and cheapest to keep clean. Re-establishment of perennials and reseeding of annuals must be prevented in any satisfactory control program.

Specific results and data are divided into regions. Work in Montana has been done in a dry cold climate, with a roadbed varying from stoney soil through gravel to cinders. Bluegrass and bromegrass, with Canada thistle, have been among the more persistent weeds. All plots in Florida have been on sand grade, sometimes with a soft limestone ballast. Bermuda grass, nutgrass, vaseygrass, and a dwarf oak have been most persistent, with Florida pusley and crabgrass as troublesome annuals. Heavy summer rainfall and a long growing season intensify the weed problem here. In Iowa, roadbeds have been on silt soils with varying quantities of gravel or cinder ballast. Quackgrass is the most troublesome perennial; foxtail grass, sweet clover, and ragweeds are the most common annuals.

RESULTS IN MONTANA

Perhaps the outstanding result in this dry, cold area has been the superiority of fall applications of chemicals such as chlorate, TCA, and CUM, the primary action of which is through the soil. The more soluble CUM (Telvar W) has been generally more effective than the dichloro form (Telvar DW). Some plots on cinder ballast treated with Telvar W and DW at 20 to 40 lb per acre in the fall of 1954 gave zero control, whereas similar treatments on soil gave excellent results. Other chemicals, also, were poor on cinders, although the differences were less striking. This problem of substrate variation must be recognized whenever applications of soil acting chemicals are used.

Other conclusions from the Montana results: Dalapon has been approximately equal to TCA. Dalapon should be used with chlorate or 2,4–D. Two lb of 2,4–D per acre was more effective against Canada thistle than 20 lb and 100 lb applied in the fall. Control of deep-rooted plants like Canada thistle depends upon the translocation of a toxic substance through living cells with respiratory energy. Any rapid toxic action will stop translocation, and the roots will be uninjured. In general, 2,4–D is less effective against deep-rooted perennials when more than 2 lb per acre is used than when used at rates of 1.5 to 2 lb per acre. TCA–chlorate, 40–80, or CM-chlorate, 10–80, applied in late September have given generally good control of vegetation for one season, with poorer results on cinder ballast. Heavy applications of CMU have controlled vegetation for three seasons in one test, but it is probable that an initial treatment sufficient to control perennials, followed by less expensive treatments to control annuals in the following season, would have been equally effective and less expensive.

RESULTS IN FLORIDA

The longer growing season, heavy rainfall (38 in to September 1 in 1955), and sandy soil and ballast create a serious vegetation control problem in the Gainesville area. Perennial grasses and sedges are the most conspicuous vegetation on most tracks, but annual grasses, broadleaf weeds, and woody plants and vines are commonly troublesome.

In contrast to Montana and Iowa, the less soluble Telvar DW (DMU) is generally better than the more soluble CMU or Telvar W. Also, Dalapon, which may be absorbed by the leaves of grasses and translocated to the roots, is probably preferable to TCA, which acts primarily through the soil and hence is more susceptible to leaching. Dalapon should, however, be more affected than TCA by light rains immediately after application.

Previous reports have noted the widely varying results obtained in past seasons with the phenyl urea compounds at Gainesville. It is unknown whether these have been due to vegetational, ballast, or climatic differences. Until these are explained, the striking results obtained with the combinations of Dalapon and Telvar DW, tried this year for the first time, must be viewed as preliminary. The effect of these two chemicals in combination was considerably better than the summation of their individual action. (Fig. 1). If these results can be repeated consistently, an effective, heavy-duty spray for the southeast may be available.

Fig. 1—Dalapon, 10 lb, plus Telvar–DW, 10 lb per acre, applied in March at Gainesville, Fla. Photo taken in November.

Selected treatments from the 1955 work at Gainsville are shown in Table 1. The control index is based on the reduction in vegetation below that in the nearest untreated control plot, with an index of 100 equaling complete control. A high average index of bi-monthly readings made during the season, and a low September 22 rating indicate

Table 1—Vegetation Control at Gainesville, 1955. Treatments on March 29

*Chemical	Rate lb/a	Control Index	
		Average	September 22
TCA	40	60	0
Chlorate	80	37	0
TCA-chlorate	40–80	70	5
Same	2 applications (60 day interval)	77	20
Same plus DW	40–80–10	71	45
DW-chlorate	10–80	66	25
Dalapon-chlorate	20–80	80	20
Same	40–80	88	35
Dalapon	10	56	15
Same	40	73	45
Telvar DW	10	28	15
Same	30	41	75
Dalapon-DW	10–10	79	90
Same	10–20	84	95
DW-Lion oil No. 7	10–100 gal	61	70

a short time control, with weeds becoming re-established toward the end of the season. Where perennials are controlled and the late weeds are annual grasses and broadleaf weeds, a second treatment with an herbicidal oil would still make an acceptable program for the season with some of these treatments.

Portions of the Seaboard Air Line Railroad track used for these experiments had been ballasted with limestone, and the phenyl ureas were appreciably more effective in these spots. It is assumed that the compounds were fixed in a less leachable form by some component or effect of the rock. The last item in Table 1, the combination of Telvar DW with herbicidal oils, was tried rather extensively in Iowa, and will be discussed later.

RESULTS IN IOWA

New experiments were started in Iowa on the effects of Dalapon, arsenicals as contact sprays, and on varying combinations of CMU with oils and with chlorate. A large experiment with TCA and chlorates, and general experiments with a number of herbicides, were continued through their third year to determine the cumulative effects of the various treatments. (Fig. 2). The season was again very dry after June, so that late applications of soil-acting chemicals were handicapped, and the effects of contact killers, as oils, enhanced by the weather.

In limited tests, Dalapon appeared to be equivalent to TCA. It has already been suggested that the former compound might be superior in the control of perennial grasses under conditions in which translocation within the plant was more effective in reaching the root systems than action through the soil.

Arsenic as sodium arsenate at the rate of 40 to 80 lb As_2O_3 per acre proved to be an effective contact herbicide. The same rates killed top growth on fairly heavy stands of mixed brush. A wetting agent at 0.1 percent of the final spray increased the effectiveness of the arsenic at the lower rate. Arsenic was once used extensively in railroad work, but has been generally discontinued because of the erratic effects of soil and weather on

Fig. 2—CMU (Telvar–W), 10 lb, plus chlorate, 80 lb per care, applied in April 1953 and April 1955 at Ames, Ia. Photo taken September 1955.

control of perennials, as well as the hazard to livestock and personnel. Rates of 320 to 640 lb per acre are not always effective on perennials, but top kill at the low rates used in our experiments was exceptionally good.

The problem of livestock losses was considered in tests of Atlas–D, an arsenical formulated with a water-soluble animal repellent. Tests with three lots of sheep indicated satisfactory repellence. The animals refused to eat the sprayed vegetation, even when penned closely on it for two weeks. Other animals on arsenic without the repellent were killed quickly. Tests under western conditions favorable to the volatilization of the repellent but not to leaching of the arsenic are still needed to insure safety in the use of the spray. Results with cattle were more variable. About half of the animals tested refused the treated vegetation. Some ate it sparingly and soon avoided it, while others showed no aversion to the repellent. One of these latter animals died after grazing for less than an hour in an area of bluegrass treated at the rate of 40 lb an acre. The repellent did, apparently, solve the problem of a positive liking for arsenic which is shown by most animals. Cattle in the tests either avoided the repellent, showed a dislike for it, or ate it indiscriminately, with no evidence of preference. Preference was shown for the regular arsenic sprays.

In experiments with CMU in oils, diesel oil was not significantly better than water as a carrier for this herbicide. Lion No. 6, an aromatic oil of diesel boiling-point range, was better than water in July sprays when CMU had little effect because of dry weather, but was not significantly better in treatments applied in April. Rates of 100 gal of oil per acre were generally better than 50 gal. An experimental, heavy catalytic cycle oil, L–8764, gave good results. There was no significant gain from the use of oil with 10 or 15 lb CMU in April. CMU was held in suspension with difficulty in the oils used.

When four herbicide oils were used at the rate of 100 gal/a, average controls were in the order Lion No. 7, L–8764, Lion No. 6, and Agronal R. Differences were small.

CMU–Chlorate Mixtures

CMU and chlorate, 10–80, were reported favorably last year on the basis of Iowa work. A factorial experiment was run this season with rates of CMU from 0 to 15 lb; of chlorate from 0 to 200 lb, and two spray dates. Results of the July application were erratic, but tended to show large effects from 100 to 200 lb chlorate. Results of the April application are shown in Table 2.

Rates of CMU, of chlorate, and interaction of CMU chlorate were highly significant. The 10–50 treatment seems out of line on the low side and the 15–200 on the high. The general effect, however, indicates the value of this combination and suggests that less than 10 lb/a actual CMU may be satisfactory in combination with 100 lb chlorate. The 5-lb rate in the Table 2, represents 6.25 lb of 80-percent powder. Eight to 10 lb of commercial CMU, plus 100 lb commercial chlorate–chloride per acre would seem to be worthy of extensive trial under Midwest conditions. A mixture of half as much CMU and twice as much chlorate might be expected to give similar effects at a comparable cost.

Repeat Treatments

One group of plots has been followed for three years with the same TCA, chlorate, sodium metaborate, wetting agent treatments repeated each year on the same plots. The readings at the end of the third year are given in Table 3. They indicate that the wetting agents have little effect in mixtures of these soil-acting chemicals; that the borate has no value at these rates, except to reduce the fire hazard in the use of chlorate, and that sodium chlorate is a good general herbicide.

TABLE 2—CMU-CHLORATE COMBINATIONS APPLIED APRIL 21, 1955

Rates—Lb/a		*Vegetation Control*	
CMU	*Chlorate*	*August 23*	*September 29*
0	100	28	67
0	200	77	84
5	0	37	72
5	50	63	87
5	100	78	93
5	200	75	91
10	0	72	85
10	50	51	75
10	100	82	84
10	200	83	91
15	0	76	91
15	50	81	93
15	100	83	88
15	200	96	97

Note: Least significant difference = 13.5 percent

TABLE 3—TCA, CHLORATE, BORATE COMBINATIONS. FINAL RESULTS AFTER THREE YEARS OF ANNUAL RETREATMENT

Rate—Lb/a			*Control*
TCA	*Chlorate*	*Borate*	
0	125	0	60
0	250	0	95
0	125	63	56
30	125	0	88
30	0	63	27
30	125	63	88.9
Same plus wetting agent	----------	----------	90.5

TABLE 4—THIRD YEAR RESULTS, VARIOUS HERBICIDES

Treatment Chemicals and Rates	*Spray Plans*			*Chemical Average*
	A	*B*	*C*	
1. CMU-10	97	94	99	97
2. CMU-20	98	97	99	98
3. TCA-40	22	71	73	55
4. Chlorate-160	72	86	98	85
5. Lion Oil No. 7, 90 gal	64	66	62	64
6. CMU-10, chlorate-80	97	98	99	98
7. TCA-40, chlorate-80	43	73	90	69
8. Same + 2,4-D-2	52	86	92	77
Spray plan average	68	84	89	80

A second block was set up with three spray plans:

A—Sprayed biannually in early May—no further treatment. These plots were sprayed in 1955 but not in 1954.

B—Sprayed annually in early May—no further treatment.

C—Sprayed annually in early May—resprayed in mid July with 60 gal L–8764 in 1953 and 1954. Weed control readings in September 1955 are shown in Table 4.

The results indicate that the more effective treatments, like CMU, could be used at lighter rates, or that cheaper treatments could be used to control annual weeds for one or two years after one CMU spray. With the TCA–chlorate spray, however, the omission of either the spring chemical or summer oil spray reduced control significantly. The major value of the late oil spray-plan C has been to prevent seed production by annual weeds in plots not receiving CMU; note treatments 4, 7, and 8.

SUMMARY

Continued experiments, particularly repeat treatments on the same plots, indicate an advantage for CMU-chlorate over TCA-chlorate. This shows not only in seasonal control but in carry-over effects. CMU-chlorate is recommended over CMU alone because of quicker action and a more general effect on all species of weeds. The results with CMU-chlorate at 10 and 100 (or 80) lb per acre and at 5 and 200 lb per acre have been nearly identical and both have been good to excellent. The 3-year experiments in Iowa indicate the probability that oil sprays could be used for one or two years after CMU–chlorate before the heavier treatment was repeated.

Excellent weed control has been obtained in Iowa with 160 lb chlorate per acre each spring, followed in July by a fairly heavy aromatic oil spray. Without the oil, results have been fair to good.

Aromatic oils at rates of 100 gal per acre have given good control of annuals and top kill of perennials. Exact specifications for these oils cannot yet be written. Aromatic content is one factor, but specific chemicals or atomic linkages may be more important than total aromatic percentages. In general, oils with good physical characteristics, aromatic percentages of 40 to 60, and 90 percent distillation points close to 700 deg F, may be expected to be satisfactory. Their actual value can be determined only by trials on plants.

Arsenites show a promise as contact herbicides that they have not shown on perennials. Available repellents have considerably reduced, but not eliminated, the livestock hazard.

Experiments in Montana have followed a trend similar to that in Iowa. Results in Florida do not fit the same pattern. Chlorates and TCA are less effective because of leaching and a long growing season. DMU (Telvar DW) appears to be better adapted to use on sandy grades than CMU. This difference may or may not hold on the heavier soils of the Piedmont. Dalapon will probably give more dependable grass control here than TCA. The striking results obtained this year with Dalapon–DMU (10–10) should be followed up intensively.

We are indebted to the Milwaukee Railroad at Bozeman, Mont., the Seaboard Air Line at Gainesville, Fla., and to the North Western and Fort Dodge lines at Ames, Iowa, for collaboration, without which these researches would have been impossible.

Part 2

Chemical Control of Vegetation—1955 AAR Report

The success of any weed control program along railroad rights-of-way is influenced greatly by several interrelated factors, such as climatic conditions (rainfall, temperature, light, periodicity, humidity and wind); type of soil or ballast; type of vegetation; type of herbicide used; proper coverage; and time of application.

Much information is available concerning each of these factors. Possibly, climatic conditions exert the greatest influence on the type and condition of vegetation found in a certain area. This of course, indirectly determines the type of herbicidal treatment which is to be used in that area. The life duration of a plant is determined to a large extent by climatic factors. Uniform climates have a tendency to be conducive to the production of perennial plants, whereas, climates with periodic changes give rise to annual and biennial plants. However, it must be remembered that perennial plants also survive in periodic climates. Also, many weeds that are annuals under severe climatic conditions may act as perennials in milder climates or in seasons with mild winters.

The relative abundance of moisture available to plants has a more pronounced effect on the type of vegetation than does any single factor of environment which determines the structure of plants. Periods of excessive and deficient rainfall are normal to all climates. The need for water is greatest during seasons with high temperatures, low humidity, and generally for those conditions favoring great losses of water not only from plants but also from the soil through evaporation. In areas where a well distributed, abundant rainfall is common, a great variety of weeds are found which maintain a luxuriant growth. The relative abundance, intensity and form of precipitation not only influences the type and luxuriance of the vegetation of a region, but also determine the type of chemical to be used in a given area. For example, soil sterilants, such as sodium chlorate, concentrated Borascu, trichloroacetic acid, Telvar W (CMU) Chlorea, Urebor, Nalco H–174 require moisture to carry the chemical into the soil. However, an excessive amount of moisture might readily leach these chemicals out of the soil. Rainfall during the period immediately following application of contact and translocated herbicides may have decided deterimental effects upon the response of the vegetation in that much of the chemical is washed from the plants before it has been absorbed by the foliage or before it has had any effect on the plants. Also, it has been noted that heavy rains which have followed applications by as much as 12 to 24 hr appear to have a beneficial effect on the results obtained. In most cases, a period of 12 to 24 hr is sufficient for the chemical to be absorbed by the plants and probably the addition of moisture increases the translocation.

Next to moisture, temperature is the most dominating factor which influences plant growth and, in turn, determines the effectiveness of a weed control program. Temperature is considered as providing a working condition for the plant functions. As the temperature increases the plant functions increase, which results in a very vigorous growth provided other environmental factors are favorable. Some weeds, such as Canada thistle and quackgrass which are not found in southern states, respond to temperature conditions. Also, some plants, such as Bermuda grass and Johnson grass, are not found in climates with changing seasons and cold temperatures. Temperature not only influences the growth of vegetation, but there is evidence that the persistence in the soil of certain chemicals such as 2,4–D and Dalapon is greatly decreased by high temperatures.

Light is another important environmental factor which determines the structure and growth of a plant. The amount of light which a plant receives often determines its

structure, its food production, influences plant distribution, and promotes reproduction. Both water and light provide actual materials essential to the building up of the structures of plants, while temperature provides the necessary working conditions.

Wind and air movement exert an influence upon both the configuration and distribution of plants. For example, the absence of trees in many locations can be due to the effect of wind. Since air movements tend to increase the rate of water loss from plants, even of plants in a dormant condition, wind during the winter months can be responsible for delineation of the boundaries of woodlands in the higher mountain ranges. Since the velocity and force of the wind increase with height above the ground level, tall growing plants, and especially trees, are exposed to both the directional mechanical and the indirect physiological effects of wind to a greater extent than low growing plants.

Effectiveness of a certain chemical on roadbeds is often influenced by the type of soil and ballast found in the area or region. A good sound ballast with good drainage which has been worked during recent years, is relatively free from vegetation, whereas, branch lines are often heavily infested with weeds. Drainage of ballast influences the type of vegetation found in a certain area. For example, some weeds, such as dandelion, pigweed, wild mustard, numerous sedges, bulrushes, and horsetail are found in poorly drained sites. On dry areas such species as annual crab grass, wild barley, thistles, nut grass, broomsedge, mullin, etc., are found. Some weeds grow on acid soils because other plants will not compete with them. Other species are tolerant of alkaline soils. Fertility of the soil plays an important part in the rapidity of growth and species found in an area. Usually, in areas where the fertility is high, a more vigorous growth and a great variety of species are common. Also, it has been stated that on cinder ballast certain chemicals, such as phenyl urea compounds, are absorbed by the cinders and become inactive as far as being absorbed by the plants.

All types of vegetation can be generally classified into three groups: annual, biennial and perennial, as determined by the life span. Along with other factors, including economy, the occurrence of these types should determine the type and rate of chemical treatment.

Annuals which have a life span of one year reproduce by seed and are somewhat easier to control than the biennials and perennials. By preventing annual weeds from seeding, the weed population can be greatly decreased.

Biennial weeds have a life span of two years. The first year's growth is purely vegetative, with seed production occurring during the second year, after which the plant dies. These weeds are controlled in the same manner as annuals.

Perennials are the most difficult to control and live for three or more years. These weeds usually produce seed during the second and following years of their life span. Some perennials reproduce solely by seed, others by bulbs, bulblets and seed; still others by stolons and rhizomes (root forms). Perennials, such as Bermuda grass and quackgrass, are shallow rooted species, whereas, Canada thistle, wild morning glory, perennial smartweed, common milkweed, horse nettle and leafy spurge are deep rooted.

One of the primary reasons for the difficulty in the control of many perennial weeds is their ability to reproduce both by seed and vegetatively. Therefore, one must check their reinfestation by preventing the old plants from producing seeds and also eradicate the established plant in order to prevent it from resprouting from the root stock.

Even though perennial weeds are difficult to control or eradicate, the population can be decreased by lowering their vigor. Since perennial plants go through a cycle of vegeta-

tion, reproduction, food storage, and dormancy, any disturbance of this cycle lowers the plants vigor.

Herbicides used primarily for weed control on railroad rights-of-way may be classified into three classes: (1) translocated, (2) contact, and (3) soil sterilants. Each of these types is effective under certain conditions.

Translocated herbicides, such as 2,4–D, 2,4,5–T, MCP, arsenic compounds, sodium chlorates, and ammate are applied to the foliage where they penetrate into the plant cells and are translocated through the xylem (water-conducting) and phloem (food conducting) cells into the entire plant system. These types of chemicals are very effective in controlling dicotyledonous plants (broad leaf species) and are very useful in controlling deep rooted perennial species. In highly developed agricultural areas, PCP is sometimes substituted for 2,4–D for controlling weeds and ammate is applied instead of 2,4–D—2,4,5–T for brush control to eliminate possible effects of drift.

Contact herbicides are used quite extensively in controlling weeds on roadbeds. These materials are used primarily to kill the tops of weeds and are not actively carried into the root system. Treatment with contact killers is successful on annual weeds and the tops of perennials, but reinfestation can occur from the surviving root stock of the perennials and later growth from seeds. Herbicides of this type which have been used on railroad rights-of-way during the past year include arsenic, sodium chlorate, petroleum oils and chlorate-chloride. The degree of their effectiveness is closely associated with the climatic conditions. In areas of high rainfall, especially immediately following the chemical treatment, results were somewhat sporadic, with reinfestation occurring 4 to 12 weeks after treatment, depending upon the intensity of the rainfall. These chemicals have been effective in decreasing some of the perennial weed populations where repeated applications have been used.

Soil sterilant herbicides are applied for action in the soil and are absorbed through the roots of the plants. There are usually two classes or types used on roadbed areas. These are classified as temporary (seasonal) and residual soil sterilants.

The temporary soil sterilants give effective results for a relatively short period of time depending upon the climatic conditions. In most cases, they are readily leached out of the soil and reinfestation by annual plants occurs during early fall. Among the chemicals of this type used this season are salts of propionic acid, salts of trichloroacetic acid, chlorates, arsenic compounds, and borate and phenyl urea combinations at low rates. Some of these compounds might be classified as semi-permanent sterilants when applied in sufficient quantities. In effect, some of the translocated and contact herbicides are temporary soil sterilants when used at high rates.

Residual soil sterilants can be effective in sterilizing the soil for a period of one year or longer, depending upon the climatic conditions, nature of the soil, and rate applied. Chemicals of this type used on roadbeds are phenyl ureas, borates, chlorates, arsenicals and others.

A joint survey of the condition of the vegetation along the roadway prior to the letting of contracts to commercial companies is usually justified. This survey aids in determining the approximate amount of chemical which will be required to cover the area to be treated. Often a great saving is possible by determining what areas should be treated and locating weed free areas which do not necessarily need treatment. Control of rates, time of application and type of treatment under system wide jurisdiction of trained personnel is valuable.

To obtain successful results, it is imperative that proper chemicals be used at sufficient rates to kill the most resistant species and to spray the entire roadbed area. Reduction

in the rate of application is common, especially, to cover a given mileage with a limited amount of chemical. The minimum rates recommended by the chemical companies are not always sufficient to give results desired by the railroads. Since the ultimate goal is complete eradication of vegetation across the ballast area, rates above minimum are more practical even if complete mileage cannot be covered. Concentration and rates depend upon the type of chemical used and the type of vegetative cover. The various rates and effectiveness are discussed more fully under the summary of the observations in 1955.

The date or time of treatment greatly influences the degree of control obtained. The time of applying soil sterilants is closely related to the seasonal rainfall. Fall applications appear to be most effective in regions of restricted rainfall. This tends to allow the chemical to be leached down into the root zone by winter and spring precipitation. In areas where the precipitation is well distributed throughout the year, a spring application or a treatment during the early growth stage appears to provide the best results. In some instances, a reinfestation by annual weeds may occur late in the season, especially in areas where high rainfall during August and September has leached the chemical below the root zone.

Brush should be treated during the season of fast growth, at which time the plant is translocating large quantities of food to the roots. This period usually occurs about the time that the plants have developed or reached the full-leaf stage of growth in the spring. Treatment is also effective during early fall at which time translocation of food materials is at a high peak. In areas where the warm season plants make a rapid growth throughout the season, it is possible to obtain effective results from a treatment applied during the fall.

A great many chemical treatments were used during the past year with varying degrees of success over the regions observed.

Dalapon with 2,4–D, was used quite extensively over a large area during the 1955 season for the control of broad-leaved weeds and grasses. Dalapon is a systemic grass killer and is absorbed through the leaves into the plant system. It is non-poisonous and does not cause fire hazards. 2,4–D is a translocated chemical, hormone type, which is absorbed by the plant growth and translocated into the roots.

Several oils were used throughout the states in 1955 as contact killers. Among the most common were Socony Mobil Agronyl R, Conoco, Standard (Sugar Creek), Shell and Cox Hykil. These oils vary in their specifications. The aromatic content varied from 50 percent to 85 percent, with end points ranging from 650 deg F to 760 deg F. Pour point varied from 30 deg F to 80 deg F. Results were effective for varying periods of time and will be discussed more fully under the observations of each region.

The actual killing properties of oils are not known, however, it is believed that the aromatic and olefine content greatly influence the plant kill. By the use of a spectrophotometer, it is possible to analyze quickly samples of herbicidal oils to determine their various properties. Tests are under way to try to correlate field results with the aromatic-olefine content found in certain oils. Further study is needed to determine if a correlation exists and to determine the property that actually causes the toxicity to plants.

Following is a summary of the chemical treatments observed in the seven regions during the past summer. Table 5 lists data concerning the composition and rates of the various materials used.

Region 1

A mixture of Dalapon and 2,4–D Amine was used quite extensively on branch and main lines successfully during 1955 when applied at the rate of 40 to 44 lb Dalapon and 8 to 9.9 lb 2,4–D per acre. Most weed species were susceptible to this treatment and

TABLE 5—CHEMICAL TREATMENTS

Chemical	*Active Ingredient*	*Rate Applied per acre of Concentrate*	*Dilution of Concentrate*
Ammate X	Ammonium sulfamate 95%	450 gal	¾ lb/gal water
Atlas D	Arsenic trioxide (As_2O_3), animal repellant 4 lb per gal	69 gal	2:3
Baron or Erbon	2-(2,4,5-Trichlorophenoxy) ethel 2,2 dichloropropionate 4 lb per gal	20–40 gal or 120–160 lb	8:1
Chlorate-Chloride	Sodium chlorate 3 lb per gallon, calcium chloride 2¼ lb per gal	40 gal	3:1
Chlorea	Sodium chlorate 40%, sodium metaborate 57% and CMU 3-(p-chlorophenyl)-1,1-dimethyl urea 1%	435–870 lb	Dry
Chlorea (liquid)	Sodium chlorate 7.15%, sodium metaborate (anhydrous) 3.92%, 3-(p-chlorophenyl)-1,1-dimethyl urea .20% inert ingredients 88.73%	80 to 165 gal	None
Concentrated Borascu	Anhydrous borax ($Na_2B_4O_7$) 85%	2830 to 5230 lb	Dry
Dalapon	2,2 dichloropropionic acid 4 lb per gal	20–40 lb or 5–10 gal	18:1 or 16:1
Dalapon	2,2 dichloropropionic acid 4 lb per gal	20–40 lb or 5–10 gal	20:4:1
2,4-D	2,4-Dichlorophenoxyacetic acid 4 lb per gal	4–8 lb or 1–2 gal	
2,4-D and 2,4,5 T	2,4-Dichlorophenoxyacetic acid, 2,4,5-Trichlorophenxoy-acetic acid 4 lb per gal	2–3 gal	100:1
Methoxone-Chlorax	(MCP) (2-methyl-4-chlorophenoxyacetic acid; sodium chlorate; sodium borate	32 gal	1:1
Methoxone-Chlorax-CMU	(MCP) 2-methyl-4-chlorophenoxyacetic acid; sodium chlorate; sodium borate; 3(p-chlorophenyl) 1,1-dimethyl urea .1 lb/gal conc.	32 gal	1:1
Nalco H-170	100% Aromatic Petroleum Oil and petroleum oil; penta-chlrophenol, Polypropoxy butyl 2,4-dichlorophenoxy acetate acid equivalent 2,4-D, .056 lb per gal.	44 gal	1:1
Nalco H-174	Sodium tetraborate ($Na_2B_4O_7.10H_2O$ 83%,(CMU) 3-(p-chlorophenyl) 1,1-dimethyl urea 8%	200 lb	none
Reade's Granacide 4X	Oil emulsion, hormone killer (2,4-D), Telvar W	44 gal	1:1
Reade's Herbicidol	Stabilized emulsion of petroleum hydrocarbon, oils, cresols, Xylenols, phenols, sodium arsenite	36–40 gal	4:1
TCA-Chlorate	Sodium trichloroacetic acid 1¼ lb per gallon. Sodium chlorate 2½ lb per gallon	33 gal	4:1
Telvar DW (DMU)	3-(3,4-dichlorophenyl)-1,1-dimethyl urea 80%	10–20 lb	.08 lb/gal water
Telvar W(CMU)	3 (p-chlorophenyl) 1,1-dimethyl urea 80%	20–30 lb	0.8 lb/gal water
Ureabor	Disodium tetraborate pentahydrate ($Na_2B_4O_7.10H_2O$) 63.2%; disodium tetraborate decahydrate ($Na_2B_4O_7.10H_2O$) 30, 8%; 3-(p-chlorophenyl) 1,1-dimethyl urea 4%	435 to 870 lb	Dry

the percentage of kill was extremely high. There was no appreciable regrowth two months and longer following application. A heavy rainfall of 3 to 4 in 6 hr after application had no adverse effects on the results obtained. Species resistant to this treatment were milkweed, bladder campion, and marestail.

Methoxone-Chlorax applied during late May at rates of 32 gal of concentrate per acre provided good weed control for 8 to 10 weeks, after which annual weeds reinfested the area. Species resistant to the Methoxone-Chlorax treatment were foxtail grass, quack grass, pigweed and Mexican fireweed. The addition of 0.10 lb per gal of Telvar W (CMU) to the mixture increased residual effects considerably and tended to provide control for the season. Methoxone-Chlorax killed both broadleaf weeds and grasses, and the rainfall, which was about normal, was sufficient to carry the CMU into the soil and prevent reinfestation by annual weeds.

Experimental herbicide M–171, now called Baron, was used to a limited extent in the yard areas in Region 1. This chemical shows promise in controlling both grasses and broadleaf species. A May application at the rate of 120 lb per acre provided an excellent initial kill. However, by August much of the area was reinfested with foxtail grass, pigweed, prostrate spurge, Mexican fireweed and bindweed. Baron appears to be more persistant in the soil than does Methoxone-Chlorax, but on the basis of limited observations appears less persistent than Methoxone-Chlorax-CMU mixture.

Nalco H–174, at the rate of 200 lb per acre, was applied during May and early June in yard areas. Results were erratic, being influenced primarily by the vegetative species and ballast. Results were poor in areas infested with sweet clover, alfalfa, milkweed, dandelion and plantain. These areas contain a high degree of cinders which possibly absorbed the CMU. Results were good on tracks relatively free of vegetation. Moisture was sufficient to carry the material into the root zone, but did not leach the chemical out of the soil.

A series of test plots with the phenyl urea compounds was applied April 1, 1955, on an area adjacent to the railroad track. Telvar W, at rates of 20 lb per acre and higher, in 250 gal of water, sterilized the soil for one season. Lowering the rate of Telvar W to 10 lb and adding 80 lb of sodium chlorate provided equivalent control. Telvar DW, which is less soluable than Telvar W, was not effective at rates up to 20 lb per acre. Species which appear to be resistant to the phenyl urea compounds were plantain, sweet clover and alfalfa.

Region 2

Dalapon and 2,4–D, at rates of 40 and 8 lb per acre, respectively, were used on a main line. The combination, applied during mid June, at which time the vegetation was making a vigorous growth, provided results similar to those in Region 1. Annual weeds reinfested the treated area late in the season. Above normal temperature and rainfall were recorded in the area during the summer, with high temperatures during August and heavy rainfalls during mid July and mid August. The heavy rainfall and high temperature, no doubt, caused the area to be reinfested later in the season.

Nalco H–174 was applied in early April at a rate of 211 lb per acre on intertrack area in a yard. This treatment was effective through July, at which time crab grass, prostrate spurge, plantain and sandbur were beginning to reinfest the area. Again, sweet clover was found to be resistant, as observed in Region 1.

Atlas D was applied during May at the rate of 69 gal per acre on main lines where livestock are kept off the track. This shows promise of being a very good contact killer.

Species resistant to Atlas D were nut grass, blindweed, trumpet vine, and blackberry brier. The trumpet vine and blackberry were defoliated but resprouted.

Chlorea was applied at a rate of 51 gal per acre during late May on a main line. Results two months after treatment were very effective. Most species were susceptible to this treatment, the more resistant species being trumpet vine, water smartweed, Bermuda grass and milkweed. The vigor of these resistant species was greatly reduced with an application of oil at the rate of 53 gal per acre during late July.

Oils were used quite extensively in Region 2 on branch and main lines this year. Standard special fuel oil which had a pour point of 30 deg F, 50 percent aromatics and an end point of 700 deg F provided effective control of vegetation for 2 months when used at a rate of 65 gal per acre during May. An excellent top kill of all vegetation was noted, with practically no appreciable regrowth until after mid July, at which time a heavy rainfall was recorded. The low rainfall during this period, no doubt, increased the length of effective control.

This same oil was applied in June on another area at a rate of 58 gal per acre on the main line. Results were very similar, except some annuals reinfested the area at an earlier date. Also, some of the perennial plants were beginning to resprout.

Socony Mobil (Agronyl R) oil, which had an end point of 760 deg F, pour point 80 deg F, and aromatic content of 64 percent, was applied in June on a branch line at the rate of 58 gal per acre. This treatment was not as effective as other oils applied at the same rate primarily because the rate was rather low and vegetation was too rank at the time of application to provide a good coverage. Better results were obtained with this oil in yard areas at 147 gal per acre.

Granacide 4X was applied at the rate of 74.57 gal per mile, or 44 gal per acre, during early July. A fair top kill was noted following application, with reinfestation occurring from annual weeds approximately 5 weeks later. There was very little residual effects observed 11 weeks following treatment. The weather in this area was hot, with intermittent showers during July, August and through mid September. Moisture was sufficient for the germination of annual weeds such as crab grass and prostrate spurge.

Nalco H–170 was applied at a rate of 36 gal of concentrate per acre in late June on a main line. This treatment was effective on the broadleaf species, but the grasses were surviving and reinfested the area. Species resistant to this application were horsetail, foxtail grass, sandbur, milkweed, and marestail.

A main line was treated in June and early July with Herbicidol at the rate of 36 gal of concentrate per acre. Results were fair, with a good top kill immediately following application, but no residual effects. Wild rose, knotweed and milkweed appear to be resistant to this treatment and were resprouting.

M–171, or Baron, was applied on test plots during mid July at the rate of 50 and 100 lb per acre. These plots were inspected a year later and found to be relatively free of grasses, but perennials were making a comeback.

Region 3

Chlorate-chloride applied at the rate of 165 gal of solution provided effective results for a season when applied during early June. This treatment was surprisingly good in one area where rainfall was recorded almost daily during July. The weather was hot and dry through August and the first of September. There was evidence of a good top and root kill, with no appreciable regrowth three months after application.

This same treatment, applied on another track, gave only fair control for the season. There was evidence of a good top kill of most vegetation one month following treatment.

Bermuda grass and nut grass were injured, however, three months after application these two species had recovered and were making a luxuriant growth.

A yard area heavily infested with nut grass was treated with Concentrated Borascu in February at the rate of 12 lb per 100 sq ft (5230 lb per acre). The weather was cool with an excess amount of rainfall from time of application through June. July was hot, with above normal rainfall, and August was hot and dry. This material was effective in killing all species except nut grass. There was evidence that some of the tops of the nut grass had been killed, but the nutlets reinfested the area three to four months after application.

Concentrated Borascu was also applied on a main line as a band treatment (3 ft width) near the ballast toe line. The material was applied in February at the rate of 7 lb per 100 sq ft (3050 lb per acre). This area was treated in March 1954 with the same material at the rate of 6½ lb per 100 sq ft on a 2-ft width. This treatment was effective in killing the vegetation and shows promise in preventing encroachment into the ballast, especially on main line tracks which are relatively free of vegetation. Most species were susceptible to Concentrated Borascu, except trumpet vine, which heavily infested the area and appeared to survive.

One railroad used the Dalapon 2,4–D mixture on its main line and yards (also used in Regions 1, 2 and 4) at the rate of 30.34 lb Dalapon and 8.27 lb 2,4–D per acre. This treatment was effective when applied in mid July. A good top and root kill existed two months after treatment. Nut grass was resistant, but showed signs of injury. Bermuda and Johnson grass were found to be surviving and beginning to recover by mid September. The weather was hot, with about normal rainfall from the date of application through the first of September.

Nalco H–174 was used on a main line as a band treatment near the ballast toe line. Application was made in December at the rate of 400 lb per acre on a 3-ft width. Rainfall was normal during the year over most of the region, but in a few areas an excess amount of precipitation was recorded. The treated area was relatively free from vegetation seven months after application. Trumpet vine appeared to be surviving in spots of heavy infestation. Possibly this could be controlled by a spot application of a translocated material such as that used on brush.

Chlorea, applied at the rate of 164 gal per acre in early June, gave effective control for two months in areas which were sparsely infested with vegetation. Results were poor on siding tracks where vegetation was heavy and rank. Some annual plants were burned, but others, such as Bermuda grass, trumpet vine and nut grass were maintaining a vigorous growth. This treatment was also used at different rates in Region 2.

A mixture of TCA-sodium chlorate was used on a main line at the rate of 40 and 80 lb per acre and controlled weeds for the season when repeated applications were applied. The first treatment was applied during mid June and was followed by a repeated application two months later. Treatment was effective on both grasses and broadleaf species (also applied in Regions 4 and 6).

Oils were used on several railroads in Region 3. Results observed on one area, which received two applications of Socony Mobil Agronyl R at the rate of 68 and 63 gal per acre during the first and second application, respectively, provided effective control from 6 to 8 weeks (Fig. 3). The first treatment was applied during May, followed by the second application during late June. This area was primarily infested with Johnson grass and Bermuda grass. An excess amount of rainfall was recorded following the first application, which permitted rapid growth. This application appeared to delay plant

Fig. 3—Region 3, Missouri. Main line which had received two applications of oil. First application was made during May at the rate of 68 gal per acre, followed by a second application during late June at the rate of 65 gal per acre.

growth two to three weeks. Six weeks following the second application, much of the Johnson grass and Bermuda grass was beginning to make regrowth.

The same oil was applied in June on another line at the rate of 90 gal per acre. Effective control was obtained for approximately six weeks, after which Johnson grass, Bermuda grass, nut grass, crab grass and annual weeds reinfested the area. Heavy rainfalls during July influenced rapid regrowth.

Region 4

Dalapon—2,4–D were used at rates of 30.24 and 8.27 lb per acre, respectively, in June on one railroad. Results were not as effective as those observed in Region 3. The length of effective control was less, probably due to excessive moisture and high temperatures. Poor results were obtained in areas of heavy rainfall immediately following application.

On another railroad, Dalapon—2,4–D were used at rates of 40 and 8 lb per acre, respectively. Results were very good for approximately 90 days, after which reinfestation occurred with annual weeds. This treatment was effective in killing Bermuda grass. Again, a heavy rainfall immediately following application reduced the percentage of kill. As indicated by these two examples, reduced control occurs when precipitation follows application before the chemicals have been absorbed by the plants.

TCA-sodium chlorate was used by one railroad at rates of 40 and 80 lb per acre, respectively. Two applications were necessary due to the long growing season and high rainfall. First application was made during April, at which time the vegetation was in the early growth stage. The second treatment was applied during the first week of September. The spring application was effective in killing the annuals, as well as controlling a high percentage of the perennial grasses. Reinfestation occurred along the ballast toe line with Bermuda grass, cow itch vine, bunch grass and some Johnson grass. The fall application should take out most of these weeds.

Concentrated Borascu was applied at the rate of 5232 lb per acre on yard and freight shed areas during February. This material was effective in killing both grasses and broadleaf plants. There was no appreciable regrowth seven months following application.

Oils were used on several railroads in this region during the past year. Conoco oil with a high aromatic-olefine content (85 percent) was applied during April on one line at the rate of 90 gal per acre. This treatment provided effective control for a period of approximately five weeks, during which time precipitation was quite heavy. Johnson grass and Bermuda grass reinfested the area by late July. A second application was made during early September. A good top burn was noted two weeks following treatment. These two treatments appear to be sufficient in keeping the vegetation burned back and in reducing the weed population. This oil was applied in the yard areas at the rate of 210 gal per acre. The top burn was more pronounced immediately following treatment, but the length of effective control was not appreciably increased.

Shell oil, with an aromatic content of 25 percent, flash point of 190 deg F, and end point of 650 deg F, with an addition of 1 percent glacial acetic acid by volume was used on one railroad. Results were favorable when applied at a rate of 55 gal per acre in April. These areas were retreated in June and September because of heavy rainfalls and long growing season. The addition of the glacial acetic acid appeared to increase the effectiveness of the oil in killing the roots of perennial species. Socony Mobil oil with the same specifications, including the 1 percent glacial acetic acid by volume, was applied on this same line. Three applications were made in April, June and September. No differences were noted between the two brands of oil.

Region 5

Most of the work observed in this region was conducted on test plot areas. Dalapon and 2,4–D at the rate of 40 and 2 lb per acre, respectively, when applied in May, provided effective results for one season on roadbed areas heavily infested with bluegrass, quackgrass, wild-rye, knotweed, Canada thistle and other species. These areas were relatively free from vegetation three months after application. This mixture was used at the rate of 30 and 2 lb per acre with less effective results on grasses, but equivalent effectiveness on broad-leaf species. Lower rates of Dalapon were used with 2 lb of 2,4–D per acre, but were not effective on grasses. Dalapon at 20 lb per acre reduced the stand of grasses approximately 50 percent. By lowering the rate of 2,4–D to 1 lb per acre in combination with Dalapon, the effectiveness in killing broadleaf species was greatly decreased.

Baron, which was used on test plots in Region 1, 2 and 7, was applied during May in test areas at the rate of 40, 80 and 120 lb per acre. The lower rate gave a quick kill of grasses and a delayed action in killing the broadleaf species. As the rate was increased, the percentage of top and root kill appeared to increase on all vegetation. Surviving species were wild rose and Canada thistle. Practically no surviving vegetation was found

on the area treated with 120 lb per acre. This chemical definitely shows promise of being effective on both grasses and broadleaf weeds in this region.

A fall application of TCA-sodium chlorate provided effective control for one season at the rate of 40–80 lb per acre. In this region, this treatment appears to be more effective than when applied during the spring.

CMU and chlorate applied at a rate of 10–80 lb per acre gave effective control for the season. CMU was not effective on tracks with cinder ballast.

Region 6

Two applications of a TCA-sodium chlorate mixture were used on a railroad at the rate of 40 and 80 lb per acre of TCA and sodium chlorate, respectively. The first application was made during April, at which time the vegetation was in the early growth stage. This application provided effective results for a period of 8 to 12 weeks. Normally, the season is dry in this section, but there was sufficient moisture to cause reinfestation, especially near the ballast toe line. A second treatment was applied during late September, which should take out most of the vegetation which reinfested the area.

Concentrated Borascu was applied during March and April around switch areas, bridges and trestles at the rate of 5232 lb per acre. Six months following treatment the soil was practically sterile.

Region 7

Dalapon–2,4–D mixture was used in test work at rates of 20 lb and 8 lb per acre of Dalapon and 2,4–D, respectively. The treatment was applied in May and was effective in killing both grasses and broadleaf species. No appreciable regrowth was evident three months following treatment.

In another area Dalapon at 20 lb per acre was combined with 4 lb of 2,4,5–T per acre (Fig. 4). This treatment was used in areas where more brushy species were prevalent, especially Himalayan blackberry and evergreen blackberry. Results were effective, with no appreciable regrowth three months later.

Baron was applied during May at the rate of 80 lb per acre in 160 gal of water. There was evidence of a good top kill of the grasses and a good root kill of some of the perennial grasses three months following application. This treatment defintely shows promise of being effective at this rate on all vegetation in this region. When used with diesel oil as a carrier, the results appear more effective, with a more pronounced kill. However, it is not known if the oil will tend to provide a more effective control for a longer period of time.

Brush treatments

Region 2

A 50 : 50 mixture of 2,4–D—2,4,5–T in 100 : 1 dilution with water was applied during July and August on one railroad at the rate of 2 to 3 gal per acre (8 to 12 lb) of acid equivalent, depending upon the condition of the vegetation (also used in Region 3). The vegetation ranged from 3 to 20 ft in height and contained species such as cottonweed, willow, elderberry, sumac, ash, sycamore, sweet gum, oak, elm, locust, and trumpet vine. Two months after treatment the percentage of kill was very good. Species which appear resistant are ash, sweet gum and some sycamore.

Region 3

One railroad was treated during July with a 50 : 50 mixture of 2,4–D—2,4,5–T in a 100 : 1 dilution with water at the rate of 2 to 3 gal of concentrate per acre. Brush

Fig. 4—Region 7, Washington. Dalapon, 20 lb, and 2,4,5–T, 1 gal, in 160 gal of water per acre, applied May 12, 1955. Picture was taken on August 22, 1955. Note good kill of blackberries.

was dense in most areas and the species most prevalent were blackjack oak, sweet gum, elderberry, persimmon, black locust, pine, poplar, sycamore, sassafras, wild cherry, sumac, hickory, honeysuckle and saw brier. Most of these species were susceptible to this treatment. Locust, and sweet gum appeared to be surviving two months after treatment, but were definitely injured.

This mixture was used during August on another track at the rate of 8 lb (2 gal concentrate) per acre. The brush species were not as rank and dense on this railroad. Species commonly found were elm, dogwood, wild cherry, cedar, sycamore, sassafras, oak, honeysuckle, trumpet vine, blackberry brier. A good kill three weeks following application was noted of all species except sweet gum, dogwood and sycamore.

A 50 : 50 mixture 2,4–D—2,4,5–T in 90: 1 dilution, with water plus 10 percent diesel fuel, was applied during August on one railroad. Brush species were 3 to 15 ft in height and consisted of blackjack oak, elm, persimmon, pine, willow, wild cherry, black gum, sweet gum, sumac, iron wood, elderberry, trumpet vine and saw brier. The 10 percent diesel fuel was added to increase the effectiveness of the treatment on pine species. It appears that the diesel fuel increased the kill of the pine. Results three weeks after application indicate an effective kill of most species in the area. Sweet gum appeared to be resistant to the treatment, but showed signs of injury.

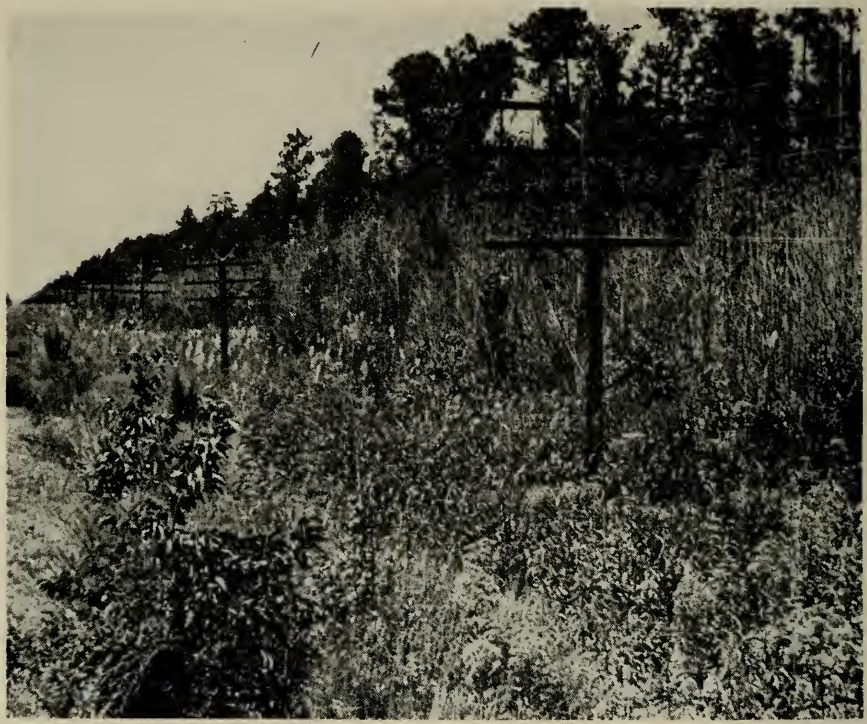


Fig. 5—Region 4, Alabama. Brush treated June 22, 1954, by helicopter, using a mixture of 15 percent 2,4,5–T in 80 percent oil with 5 percent emulsifier applied at the rate of 2.8 lb acid equivalent per acre. Picture was taken on September 9, 1955.

Region 4

Observations were made on an area adjacent to a railroad track which was treated by helicopter during June 1954 with a mixture of 15 percent 2,4,5–T in 80 percent oil, with 5 percent emulsifier (Fig. 5). This material was applied at the rate of 3.75 gal of mixture per acre (2.8 lb acid equivalent). There was evidence of a good kill 15 months after application. Sweet gum, ash, pine and bay were the only species which were resistant to the treatment. Some of the tops of these species were killed, but sprouted from the root stock. This treatment is quite expensive, but may be justified in areas which are inaccessible with on-track equipment.

A 50 : 50 mixture of 2,4–D—2,4,5–T was used during July on a railroad at the rate of 2 gal per acre (8 lb) with much success. Species commonly found in the area were ash, bay, willow, oak, pine, sweet gum, and elderberry. This treatment provided effective kill of all species except sweet gum, ash and bay. However, these species were severely injured. This mixture was used at the same rate on another railroad during September, but was inspected too early to evaluate the percentage of kill.

Report of Committee 5—Track

L. L. Adams, *Chairman,*

W. E. Cornell,
Vice Chairman,
A. F. Huber (E),
Secretary,
W. G. Arn (E)
H. S. Ashley
John Ayer, Jr.
T. H. Beebe
F. J. Bishop
M. C. Bitner
W. R. Bjorklund
J. C. Brennan
E. G. Brisbin
R. J. Bruce
T. F. Burris
H. F. Busch
M. D. Carothers
E. W. Caruthers (E)
H. B. Christianson
C. A. Colpitts
E. D. Cowlin
F. W. Creedle
P. H. Croft
L. E. Donovan
K. E. Dunn
H. F. Fifield
J. W. Fulmer
R. G. Garland
L. W. Green
W. E. Griffiths
V. C. Hanna
M. J. Hassen
D. C. Hastings
A. E. Haywood
C. C. Herrick
A. B. Hillman
J. W. Hopkins*
C. T. Jackson (E)*
H. W. Jensen
L. H. Jentoft
C. H. Johnson
C. N. King
T. R. Klingel
C. J. McConaughy
E. R. Murphy
W. N. Myers*
H. B. Orr
M. P. Oviatt
J. S. Parsons
C. E. Peterson
S. H. Poore
J. M. Rankin
J. A. Reed
M. K. Ruppert
W. A. Schubert
R. D. Simpson
R. C. Slocomb
T. R. Snodgrass
G. R. Sproles
R. E. Tew
R. H. Timmins
Troy West
K. H. Von Kampen
D. J. White
J. B. Wilson
M. J. Zeeman

Committee

(E) Member Emeritus.
* Deceased.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report. See report on Assignments 2, 3 and 9.

2. Track tools, collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR.

   Part 1—Recommendations submitted for adoption and publication in the Manual ..... page 685

   Part 2—Progress report, submitted as information ..... page 686

3. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR.

   Offers recommendation affecting Portfolio of Trackwork Plans ..... page 686

   Appendix 3–a—Service tests of designs of manganese steel castings in crossings at McCook, Ill.

   Progress report, presented as information ..... page 687

Appendix 3–b—Service test of solid and manganese steel insert crossings supported by steel T-beams and longitudinal timbers.

Progress report, presented as information ..... page 689

4. Prevention of damage resulting from brine drippings on track and structures, collaborating with Committee 15 and Mechanical Division, AAR.

Progress report, presented as information ..... page 696

5. Design of tie plates, collaborating with Committees 3 and 4.

Progress report, presented as information ..... page 700

6. Hold-down fastenings for tie plates, including pads under plates, their effect on tie wear, collaborating with Committee 3.

Progress report, presented as information ..... page 707

7. Effect of lubrication in preventing frozen rail joints and retarding corrosion of rail and fastenings.

Progress report, presented as information ..... page 735

8. Laying rail tight with frozen joints.

Progress report, presented as information ..... page 760

9. Critical review of the subject of speed on curves as affected by present-day equipment, collaborating with the AAR Joint Committee on Relation Between Track and Equipment.

Offers material for adoption and publication in the Manual as a substitute for the material appearing on pages 5–3–9 to 5–3–12, incl., beginning with Elevations and Speeds for Curves" ..... page 764

10. Methods of heat treatment, including flame hardening, of bolted rail frogs and split switches, together with methods of repair by welding.

Progress report, presented as information ..... page 768

THE COMMITTEE ON TRACK,
L. L. ADAMS, *Chairman.*

AREA Bulletin 528, February 1956.

MEMOIR

John William Hopkins

John William Hopkins, engineer of track for the Bessemer & Lake Erie Railroad, suffered a coronary occlusion and died in Birmingham, Ala., during the night of April 4–5, 1955.

Mr. Hopkins was born in Philadelphia, Pa., on November 13, 1903, and received his technical education at Lehigh University and Pennsylvania State College, graduating from the latter with the degree of B. S. in Civil Engineering. Prior to his railroad service he was division bridge engineer of the Pennsylvania Department of Highways, and designer and field engineer for J. B. Long, consulting engineers, Norristown, Pa. He had been associated with the Bessemer & Lake Erie for the past 18 years.

Mr. Hopkins had been a member of the American Railway Engineering Association since 1943 and had served on Committee 1—Roadway and Ballast, Committee 5—Track, and the Special Committee on Continuous Welded Rail. He was also a member of the American Society of Civil Engineers, the Roadmasters' and Maintenance of Way Association of America, and was a registered professional engineer in Pennsylvania. He was a member of the Phi Sigma Kappa Fraternity, of Eureka Lodge, F. and A. M., and of Lodge No. 145, B. P. O. E., Greenville, Pa.

He was keenly interested in civic affairs and was serving as chairman of the Municipal Authority of the Borough of Greenville Water Department at the time of his death.

The Association has lost a valued member and those with whom he was closely associated have lost a sincere friend.

W. E. Cornell
J. S. Parsons
F. J. Bishop
Committee on Memoir.

Report on Assignment 2

Track Tools

Collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR

C. E. Peterson (chairman, subcommittee), L. L. Adams, H. S. Ashley, F. J. Bishop, T. F. Burris, E. W. Caruthers, W. E. Cornell, L. E. Donovan, K. E. Dunn, A. E. Haywood, C. N. King, C. J. McConaughy, J. M. Rankin, R. C. Slocomb, Troy West, J. B. Wilson.

Part 1

As the Manual does not contain a chemical specification for carbon steel track tools, your committee submits the following chemical specification as recommended practice for adoption and publication in the Manual, to be inserted under the list of plans for track tools on page 5–6–9:

Chemical Specification for Carbon Steel Track Tools

†Carbon	0.55 to 0.70	Phosphorous	0.05 max
Manganese	0.60 to 0.90	Sulphur	0.05 max

† Applies to all carbon steel tools except track chisels, which are to be of 0.80 to 0.90 carbon.

Due to the high cost of labor in the field, it is recommended that initial handles be inserted in the small-eyed track tools by the manufacturer before being shipped.

The cost of each such tool will thus be increased 45 cents for the short handle and 90 cents for the long handle, fitted and inserted, over what the tools would nominally cost the railroads. A shop-fitted handle will fit properly, and the cost will be less than when done in the field.

Your committee submits the following as recommended practice for adoption and publication in the Manual, to be inserted as a footnote to the list of plans for track tools on page 5–6–9:

* Unless otherwise specified, the small-eyed track tools will be furnished with AREA handles. The handles are to be properly fitted and wedged; 36-in handles are to be furnished for tools weighing 6 lb and over, and 16-in handles for tools weighing under 6 lb, except that 24-in handles are to be furnished for track chisels and tie plug punches.

Also, an asterisk is to be placed in front of the following tools on page 5–6–9 (to which the above note applies): spike maul, adz, sledge, tie plug driver, track chisel, track punch and tie plug punch.

Part 2

The following is a progress report, submitted as information.

Claw Bar

The claw bar study is being continued. A number of modified claw bars were tested in the field, but no conclusions have been reached as to the need for a change in design.

Standardization of Paint Colors on Track Tools

A study is under consideration looking to the standardization of colors of paint used on track tools, i.e., to specify one particular color for alloy steel tools and black for carbon steel tools, so the color of tools furnished by all tool manufacturers will be consistent.

Report on Assignment 3

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section, AAR

M. J. Zeeman (chairman, subcommittee), L. L. Adams, T. H. Beebe, W. R. Bjorklund, R. J. Bruce, T. F. Burris, H. F. Busch, M. D. Carothers, E. W. Caruthers, H. B. Christianson, W. E. Cornell, E. D. Cowlin, F. W. Creedle, L. E. Donovan, J. W. Fulmer, V. C. Hanna, M. J. Hassen, A. E. Haywood, A. B. Hillman, A. F. Huber, H. W. Jensen, C. H. Johnson, T. R. Klingel, C. J. McConaughy, H. B. Orr, C. E. Peterson, S. H. Poore, J. A. Reed, R. D. Simpson, R. C. Slocomb, T. R. Snodgrass, R. H. Timmins, K. H. Von Kampen, Troy West, J. B. Wilson.

In the 1955 report of the Track committee under Assignment 3, 11 general revisions in the Trackwork Plans and Specifications, affecting some 88 plans, were presented for adoption. Among these was Revision III, reading "Depression of Frog Points. The depression of all manganese frog and crossing points for angles below 25° where wing wheel risers are not used, and of all spring frog points, is recommended", which revision affected 26 plans. This Revision III was approved at the 1955 convention.

The advantages of Revision III apply equally to rail-built rigid frogs and crossings, Plans Basic Nos. 320, 322, 323, 324 and 710, but, unfortunately, this was overlooked in the volume of work undertaken for the 1955 report. Since these plans were reprinted for the 1955 Supplement to the Portfolio of Trackwork Plans to take care of other revisions, it was decided to include Revision III in this printing in order to save expense. The matter was submitted to the Board of Direction by the secretary of the Association and the Board agreed to this action, provided it would be submitted to the 1956 convention for final approval.

Accordingly, your committee presents for adoption as recommended practice the inclusion of Revision III—Depression of Frog Points, on the following plans:

320–55—Data and Sections for Bolted Rigid Frogs
322–55—No. 4, No. 5 and No. 6 Bolted Rigid Frogs
323–55—No. 7, No. 8 and No. 9 Bolted Rigid Frogs
324–55—No. 10, No. 11 and No. 12 Bolted Rigid Frogs
710–55—Bolted Rail Crossings, Angles 14°15′ to 8°10′

The collaboration of the Standardization Committee of the Manganese Track Society in our work on various subjects is gratefully acknowledged. This work includes study involving some new plans, also possible future revisions of some existing plans in order to incorporate any improvements we may wish to submit for your approval.

Reports by the Research Staff, AAR

Your committee presents as information the following reports prepared by the research staff of the Engineering Division, AAR:

Appendix 3–a—Service Tests of Design of Manganese Steel Castings in Crossings at McCook, Ill. Progress report.

Appendix 3–b—Service Tests of Solid and Manganese Steel Insert Crossings Supported by Steel T-Beams and Longitudinal Timbers. This is a final report.

These two subjects were reported on last year in Appendices 3–a and 3–b, respectively, and published in the Proceedings, Vol. 56, 1955, pages 747 to 751, incl.

There is no report to make this year on the subject: Specifications for Spring Washers for Use in Special Trackwork. This subject was reported last year in Appendix 3–c and published in the Proceedings, Vol. 56, 1955, pages 752 to 820, incl.

Appendix 3–a

Service Tests of Solid and Manganese Steel Insert Crossings at Mc Cook, Ill.

This report covers the service performance of the solid manganese steel test castings in the crossings between the double-track lines of the Baltimore & Ohio Chicago Terminal Railroad, and the Atchison, Topeka & Santa Fe Railway at McCook, Ill., and is offered as information.

Foreword

Four of the AAR–B&OCT test castings remain in service and each are in the same location as last reported. Two of the castings are of the solid pedestal design furnished by the Johnstown Works of the United States Steel Corporation. Both of these castings are in the crossing which carries eastward traffic on both sides. The other two castings were furnished by the Ramapo Ajax Division of the American Brake Shoe Company. One of the Ramapo castings is of the deepened flangeway design and is located in the NE corner of the crossing carrying westward traffic on both sides. The other casting is of the Morden–Ramapo design, which had its flangeways shot-peened prior to installation. The second casting of the deepened flangeway design, which was provided by the B&OCT, was removed in August 1955 to permit Ramapo to make a laboratory investigation of the flangeway gage wall cracks. When the inspection was made July 20, 1955, the shot-peened casting had 6.2 years of service and the other three castings, 2.8 years. A description of the later designs was published in the Proceedings, Vol. 55, 1954, pages 13–16, and the last report on this investigation is in the Proceedings, Vol. 56, 1955, page 747. The results of the later inspections are given in the following paragraphs.

USS Solid Pedestal Castings

These two castings are of identical design, except one was depth hardened and the other one was left in the as-cast and ground condition. The flangeway cracks in the depth-hardened casting increased from 8⅛ in. in August 1954 to 25¼ in. in July 1955.

Most of this accelerated rate of crack development occurred between inspections made in November 1954 and March 1955, or during the third winter. Over one-half of the crack length was adjacent to the B&OCT receiving—Santa Fe leaving corner. There were no cracks at the guard rail junctions. The unhardened USS casting had 15¼ in of flangeway cracks and a short crack at each guard rail junction. There were only 2½ in of flangeway cracks in August 1954. The depth-hardened casting has continued to develop more cracks than the unhardened one.

Ramapo Deepened Flangeway Casting

The remaining Ramapo casting of the deepened flangeway design had one 5-in crack. This crack was near the middle of the flangeway floor in the Santa Fe external arm and was not in the fillets. This casting had no cracks at the guard rail junctions. The flangeways of this frog, including the deepest portion, were ground to a smooth finish by the supplier.

Welding of the 1952 Castings

The B&OCT furnished a record of the number of times and the dates of the welding of the three 1952 castings. Because there is no information as to the extent of the welding each time, or whether one or three tread corners were built up or flangway wall cracks ground out and welded, the number of times each casting was welded cannot be a precise yardstick for comparing depth-hardened castings with non-depth-hardened frogs. All of these castings were placed in service in October 1952. The first welding work performed on the USS non-depth-hardened casting was after 18 months of service. Both the USS and Ramapo depth-hardened castings were first repaired by welding after 26 months of service, or 8 months after the USS plain casting was welded. Eight months of traffic over the crossing in which the USS castings are located is conservatively estimated to be equivalent to 40 million gross tons of traffic.

Shot-Peened Casting, Morden–Ramapo Design

The flangeway cracks in this casting increased from 33 in. in August 1954 to 34½ in. in July 1955. There were no cracks extending from the guard rail junctions. The two cracks of total length of 1¾ in on the top surface at the Santa Fe running rail junction (as previously reported) were repaired by welding, April 1955. At that time the tread corners were built up. Although this frog has little room for additional cracks, the tread corners were in reasonably good condition and there were no defects visible in the flangeway walls. The long life of this casting under heavy traffic can be attributed partly to the fact that the welded metal has given good service.

On November 11, 1955, the test castings were inspected again. The shot-peened casting had developed a vertical crack in the outer wall of the Santa Fe internal arm. In addition, the long 14½-in flangeway fillet crack in the same arm had turned upward and extended ¾ in on the Santa Fe running surface. Because of the general deteriorated condition of this casting, it will be retired during the winter of 1955–1956.

Supplemental Inspection

This inspection was made in August 1955 to determine the extent of the cracks observed in the flangeway gage walls in the previous month. The USS depth-hardened frog had a "C" shaped crack adjacent to the two receiving corners. These cracks started near the bottom of the flangeway at the gage intersection, extended upward to ¾ in below the top of the casting and then down to near the flangeway floor. The cracks had chord lengths of 3 in and 3¾ in, as measured along the length of the respective arms

of the frog. The USS non-depth-hardened casting had one crack adjacent to the Santa Fe receiving—B&OCT leaving corner, 4½ in long, which extended from a point near the gage intersection and ¾ in below the top or running surface to near the flangeway floor. The deepened flangeway frog had a sloping crack that extended around the gage intersection of the Santa Fe receiving corner for a distance of 5 in. in the Santa Fe flangeway and 3½ in. in the B&OCT flangeway. The crack was 1 in below the top at the gage intersection and sloped upward in both directions to ½ in below the top of the castings. The deepened flangeway castings provided by the B&OCT also had some cracks in the flangeway walls. For the purpose of making a laboratory investigation of this design, it was removed in August 1955 and shipped to the Ramapo Ajax Division.

These flangeway wall cracks, no doubt, indicate the beginning of progressive fractures which may cause parts of the tread corners to break out. Because of the heavy tonnage carried by these crossings, particularly in the B&OCT eastward track, three years of service at that location is equivalent to the traffic carried by the average crossing for six or more years.

Autumn Inspection of the 1952 Castings

This inspection was made November 11, 1955. At that time it was found that the USS depth-hardened casting had been welded in September 1955, and most of the flangeway wall cracks had been ground out and repaired by welding. The flangeway wall cracks in the USS non-depth-hardened casting and the Ramapo deepened flangeway depth-hardened casting had not been ground out and welded.

Acknowledgement

The Association is indebted to the B&OCT for its cooperation and assistance in the conduct of the service tests and extends its appreciation to the suppliers for their assistance.

Appendix 3–b

Service Tests of Solid and Manganese Steel Insert Crossings Supported by Steel T-Beams and Longitudinal Timbers

This is the final report on this subject and is presented as information. The investigation was conducted under the general direction of G. M. Magee, director of engineering research, Engineering Division, AAR. The assignment was under the direct charge of H. E. Durham, research engineer track, AAR, who was assisted by A. D. Van Sant, assistant research engineer track, and other staff members.

INTRODUCTION

The purpose of this investigation was to develop an integrally welded steel T-beam type of frog support for crossings to reduce the flexural stresses in the castings and to determine its practicality under actual use through the medium of a service test.

It was known from previous stress measurements taken in the flangeways of castings that there is considerable variation in the type of stress to which a crossing frog is commonly subjected (Proceedings, Vol. 48, 1947, pages 563–568). Since the principal reason for this general reversal of stresses was attributed to flexure, it was thought that a stronger type of substructure would reduce the flexure of the assembly and consequently reduce or delay the formation of flangeway cracks in the manganese steel castings.

Accordingly, arrangements were made with the Ramapo Ajax Division of the American Brake Shoe Company, the Indiana Harbor Belt Railroad and the Chicago and Western Indiana Railroad (operated by the Belt Railway Company of Chicago) for the fabrication and installation of four test crossings, two with T-section supports and two with longitudinally framed crossing timbers and crushed rock ballast. The steel T-section supports were to be imbedded in asphalt bound crushed rock ballast. One each of the two crossings in each group was to be a reversible manganese insert type and the other, a solid manganese type. The basic plan dimensions of the T-section support called for a 20-in wide flange on the top of the "T", with a 1-in thickness of plate. The stem was 12-in deep by 1-in thick. These sections were welded together into one integral unit and provided a running length for each rail of the crossing. The frog castings were fastened to the steel T-beam supports with clips and heat-treated bolts.

On October 14, 1946, the experimental installation was made at the double-track crossings of the IHB and C&WI near 55th St. and Cicero Ave., Chicago (Fig. 1). Flangeway cracks were observed in the frogs after two years of service at this location. Even though the traffic was slow to moderate speed freight movement, there was a fairly heavy tonnage, particularly on the C&WI northward track. A detailed description of the installation and the results of a concurrent strain gage measurement test on the solid manganese design of crossing frog and T-beam support were published in the Proceedings, Vol. 48, 1947, pages 563–568.

From the stress measurements made on the 1946 design of T-beam support, it was known that at least one of the vertical welds in the discontinuous T-beam web had failed. The 1949 design was improved by changing the dimensions of the web plates from 1 by 12 in to 1½ by 10 in and using double instead of single V welds. The two solid manganese crossings (AREA Plan 771–40) and one T-beam support, which were manufactured by the Pettibone Mulliken Corporation, were placed in service on May 6, 1949, at the intersection of the Elsdon Branch of the C&WI and the same north–south tracks as in the previous test. The structural steel support was placed under the northward crossing while the southward installation was supported with longitudinal timbers under the north–south rails. Both of these crossings were ballasted with crushed stone. All of the 6 test crossings had a casting height of 6 in.

RESULTS OF INVESTIGATION

Types of Ballast Under Steel T-Beam Supports

One of the supplementary experiments which was given attention during this investigation was the addition of an asphalt to the crushed rock ballast under and around the 1949 steel T-section support. It was thought that the steel supports could be more readily supported with the addition of a binder to the ballast.

In the 1946 installation, a cut-back mix, in which a volatile solvent was added to the asphalt in order to liquefy it, was used. The combination of crushed rock and asphalt was premixed and delivered hot to the site by truck. Since it was impossible to compact this mix sufficiently at the time of installation, it was necessary to tamp the T-section frequently during the first month of operation. Because the mix initially set up on the surface, preventing the solvent from evaporating from the inside, the interior portion of the mix remained in a viscous state which was not able to give support for about two weeks.

After the asphaltic concrete ballast had become more stable, it was necessary to surface the crossings only twice a year. However, the asphalt base crossings required two

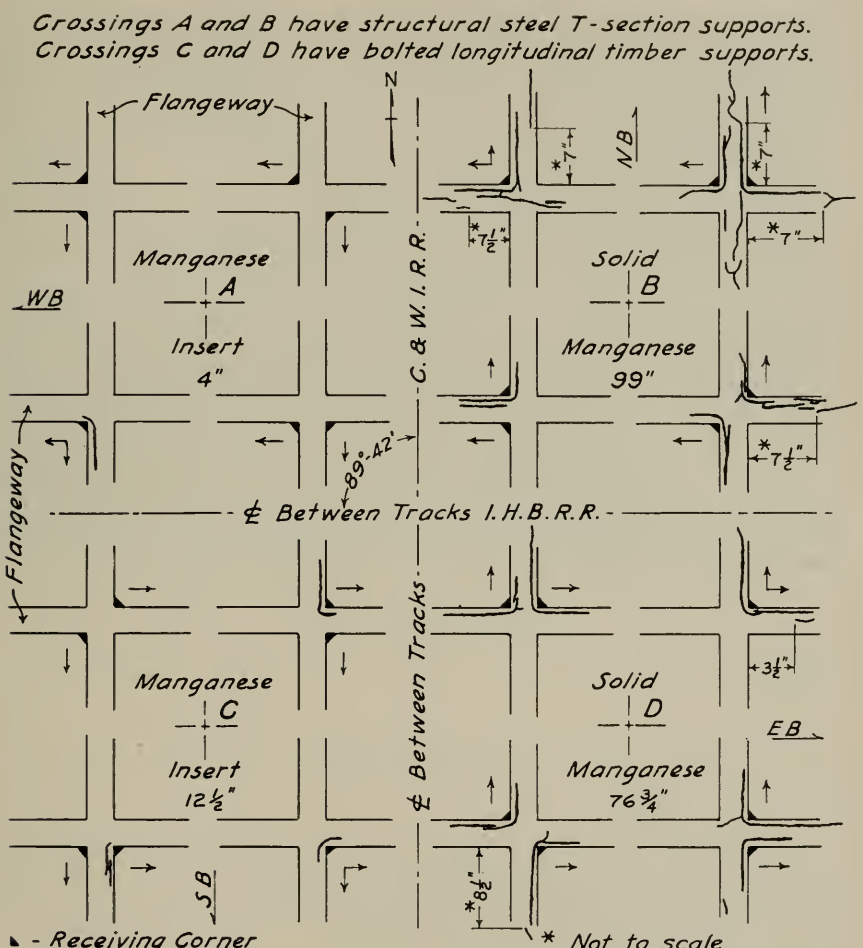


Fig. 1. - Flangeway Cracks in Four Crossings of the Chicago & Western Indiana R.R. and Indiana Harbor Belt R.R. near 55th Street and Cicero Avenue, Chicago, Illinois.

lifts during the surfacing operation as compared to one lift for the timber-supported installations. The initial instability no doubt contributed to the early formation of the cracks in the substructure welds.

This preliminary study gave rise to a second experiment with an asphalt-impregnated ballast. Approximately 1½ years after the installation of the 1949 crossings in the Elsdon Branch, an asphalt of 85–100 penetration was heated to 350 deg F and added to new crushed stone ballast by the penetration method. It was found to be very impractical to maintain grade on the steel supports on top of stone ballast with no binder. The main-

tenance expense was considerable. Unlike the timber supports, which allow the rock ballast to be confined by the imbedding of the stone into the wood, the steel sections forced the rock out from underneath the supports. This condition possibly could have been alleviated by the addition of lips to the T-flanges or the insertion of wood sections on the underside of the same.

This second installation did not hold up well as had been anticipated. It was impossible to keep the crossing from swinging and in good surface because of roadbed instability and lack of drainage. This condition caused the water to pump out and to flow back into the center of the diamond under the traffic, and consequently it was confined by the 10-in deep T-beam webs. However, it was demonstrated, from the original installation in the 1946 crossings, that with good drainage the asphaltic concrete ballast practically eliminated muddy conditions.

The first installation of asphalt concrete ballast under two of the supports was maintained until April 1952, at which time the crossings were lined, and the original ballast dug out and then backfilled with ¾-in stone. The old asphaltic concrete ballast was quite difficult to remove.

Much of the underlying difficulty of maintaining a good practical steel T-section support could be traced to the inability of the ballast to function properly around it.

In addition to some of the previously mentioned suggestions which might alleviate this condition, it should be stated that in comparing service results of the asphalt type vs the crushed stone ballast, there apparently is a much better opportunity to maintain surface by supporting the T-beams with well-graded stone and tamping with a vibratory-type tamper, provided a lip is welded on the flange edges or timbers fastened underneath. The crushed stone ballast underneath the timber-supported castings performed satisfactorily.

PERFORMANCE OF STEEL T-BEAM SUPPORTS VERSUS LONGITUDINAL TIMBER SUPPORTS

Steel T-Beam Supports

On March 31, 1955, the 3 steel T-beam substructures under the test crossings were retired from service in connection with raising the crossings 4 ft. The 2 original steel supports were in service approximately 8½ years. The third section, referred to as the "1949 installation", served in track for almost 6 years.

As stated previously, the 1949 installation had incorporated improvements into the design and fabrication of the steel T-beam section. One of the most important differences was in the welding of the T-joint juncture of the stem sections. The new substructure had a double bevel on the ends of the plates abutting the through plates, and the welding extended across the entire thickness of the 1½-in plate as well as the length. Since strain gage measurements on the original section had revealed the apparent failure of these critical welds, there was a definite need for a revision in plans.

An examination of the sections after they were taken out of track verified some of the theories which were advanced previously. The original substructure under the solid manganese casting (crossing B in Fig. 1), which served the northward Belt Railway and the westbound IHB, was in poor condition. The welds between the stems and the flanges were intact only out toward the extreme ends of the sections where the triangular stiffeners had been placed. All the vertical welds between the web plates had failed. The failure of the T-beam support probably contributed to the formation of more flangeway cracks than in the solid castings on timber.

Fig. 2—Original (1946) steel substructure after 8½ years of service under crossing "A".

A close-up photograph of the underside of the northwest corner of the original substructure, which supported the manganese insert test crossing (commonly referred to as "A") between the southward C&WI and the westward IHB tracks, is presented in Fig. 2. It is clearly shown how the welds had failed between the flange and web extending out from the intersection a distance of 15 to 19 in, and also how the welds had cracked vertically at the discontinuous web plate. All of these vertical cracks appeared in the same relative position—under the receiving corners of the C&WI southbound traffic. In other words, all of the vertical weld failures were on the south side of the continuous E–W web members. This condition prevailed in three out of the four corners of the structure. The fourth, which was actually the SW corner, showed no signs of failing.

In contrast to the original installation, a photograph is presented in Fig. 3 of the improved T-beam substructure, which proved to be of adequate strength. There were no visible failures at any place in the sections which had supported the solid manganese crossings in the 1949 Elsdon Branch installation.

One of the reasons why the steel supports did not function properly stemmed from the inability to hold the castings tight to the substructure. As designed, the two independent parts were supposed to act as one unit and thereby reduce the amount of flexure and stress in the castings. The special clamps were aggravated constantly by the cycle of impacts. They were frequently found to be loose, with some of the clip bolts broken.

Longitudinally Framed Crossing Timber Support

The performance of the timber supports during this investigation indicated that the method generally was satisfactory. The supports provided a certain degree of flexibility and still were quite rigid. For the most part, the crossings were not difficult to maintain and were comparatively easy to aline.

Fig. 3—Improved (1949) design steel substructure after 6 years of service under solid manganese steel crossing.

THE EFFECT OF THE TYPES OF SUPPORT ON THE MANGANESE INSERT AND SOLID MANGANESE CROSSINGS

Each year, two or more inspections of the crossings were made by the members of the research staff and some of the suppliers. A diagram was presented annually in each progress report in order to follow the development of flangeway cracks in the four crossings. Fig. 1 is a reprint of the test crossings showing the extent of the fatigue cracks as of August 12, 1954. The figures in each crossing represent the total accumulated length of the cracks for each installation. The length of each crack is shown to the same scale as the flangeway width, except as noted. As can be seen from the drawing, the steel support was moderately beneficial in the retardation of the flangeway cracks in the insert-type crossings, but not for solid crossings. The Elsdon Branch installation of 1949 had a total aggregate length of cracks amounting to 91 in. in the solid manganese crossing on steel support, compared to 55½ in of cracks in the same design of crossing on timber. In addition, there was a 5-in crack in the top of the casting of the former, but it was outside of the wheel path between the external arms of the NE corner. The steel-supported crossing carried greater tonnage than that with the timber.

After the asphaltic ballast had become stable, the maintenance of the original 1946 installations involved surfacing twice a year, regardless of the type of support or ballast. However, it was necessary with the steel supports on asphaltic concrete ballast to give the crossings at least two lifts during one to two weeks time in order to maintain the desired grade. This schedule was kept until April 1952 when the asphaltic ballast was removed and the crossings were alined. Until that time no welding had been done on the insert crossings, with only a nominal amount of welding being done on the tread corners of the solid castings. In the fall of 1953, it was necessary to build up all four

crossings by welding. At this time there was a general surfacing of the installation as a whole, and the crossings were placed in good line and surface. No record of the maintenance costs was kept for the 1946 installations.

The installation in 1949 afforded an opportunity to keep a record of the cost of maintaining each of the two crossings. The following table is presented to give a comparative evaluation of the number of manhours spent in surfacing the two test installations, and of the total maintenance cost:

Date	*Crossing on Timber*		*Crossing on Steel Substructure*	
	Man-Hours Surfacing	*Total Maintenance Cost*	*Man-Hours Surfacing*	*Total Maintenance Cost*
May 1949 April 1950	15	$ 32.11	43	$ 70.79
May 1950 April 1951	30	59.14	60	311.72
May 1951 April 1952	0	29.38	85	162.01
May 1952 April 1953	30	80.73	114	250.90
May 1953 April 1954	14	59.80	145	279.47
May 1954 March 1955	15	58.61	97	206.35
Total	104	$319.77	544	$1281.24

Notes: In November 1950, the crossing on steel support was lined and the old rock ballast was removed. New crushed rock (1½-in maximum size) was placed in layers and hot paving asphalt was poured on the layers. During the third year, the steel-supported crossing was surfaced with fine "black top" three times.

The excessive maintenance cost of the steel-supported crossing consisted largely of surfacing, changing the stone ballast to a penetrated asphalt ballast, and repairs by welding. During the last service year, it was necessary to replace the east half of the crossing with a used casting because of the failure of the solid manganese casting on the steel support. The entire crossing on the steel support was retired during the summer of 1955 and replaced with a new articulated manganese crossing to match the height of 115 RE rail. The 1949 solid manganese crossing on timber was left in service.

SUMMARY AND CONCLUSIONS

After 6 years of testing knowledge gained from the 1949 installation, in addition to the 8½ years of experience with the 1946 test set-up, the following points are of particular interest:

1. The revised design of T-beam support was of adequate strength to support the crossing.
2. The steel substructure was moderately beneficial in reducing the extent of flangeway cracks in the manganese-insert type of crossing.
3. The solid manganese crossing with steel support developed more flangeway cracks than the comparable installation on crossing timbers.

4. The asphaltic concrete ballast in the 1946 installations, where good drainage was provided, was very effective in preventing muddy conditions.
5. A vertical lip welded along the edges of the T-beam flanges would greatly facilitate the retaining of the ballast under the steel plates. Another method which might accomplish the same result is the bolting of treated hardwood timbers to the underside of the flanges so that the stone ballast would become imbedded in the wood and resist dislodging by the impacts. The plan of having the lip on the edges of the T-beam flange with graded ¾-in maximum stone ballast and vibratory tamping appears to be the most practical.
6. In order to have the steel substructure and the crossing flex and function as a unit, and thus reduce the bending stresses in the casting, a greatly improved design of clamping arrangement must be provided.

Acknowledgement

The Association is appreciative of the splendid cooperation received from the IHB, the Belt Railway, Ramapo Ajax Division of the American Brake Shoe Company, and the Pettibone Mulliken Corporation. The conduct of this investigation depended to a great extent on their invaluable assistance.

Report on Assignment 4

Prevention of Damage from Brine Drippings on Track and Structures

Collaborating with Committee 15 and Mechanical Division AAR

W. E. Cornell (chairman, subcommittee), L. L. Adams, H. S. Ashley, John Ayer, Jr., H. F. Busch, L. W. Green, E. R. Murphy, J. S. Parsons.

This is a progress report, submitted as information.

Laboratory work was continued at the AAR Research Center in the search for more efficient inhibitors against the corrosive action of brine solutions, under the general direction of G. M. Magee, director of engineering research, Engineering Division, and under the immediate supervision of S. K. Coburn, chemical engineer. Participating in the experimental program were K. J. Morris and J. Oda. Earlier work described previously (Proceedings, Vol. 55, 1954, page 1084, and Vol. 56, 1955, page 820) indicated the progress made in developing a test chamber for carrying out accelerated exposure tests on coupons by means of varying humidity. Additional obstacles overcome were means for precleaning the test specimens as well as the quantitative removal of corrosion products from the specimens following exposure. Work was initiated toward learning what optimum exposure period was necessary to obtain valid reproducible results.

During the past year several three-month tests were carried out, using both known and new inhibitor materials. Of these, a number of inorganic salts were found to be unsatisfactory. Several organic compounds were evaluated and found to have little inhibiting capacity. It is felt, however, that new progress is likely to be made in this field, since several organic chemical manufacturers are catering to the needs of the oil well drilling industry and making available numerous new compositions. These will be examined in the test chamber as soon as they are made available. As a result of these three-month tests, confirmation was obtained as to their superiority over the one-month exposure tests. The type of corrosion produced is similar to that found in rail exposed to brine traffic over a period of 10 to 20 years.

Presently, the best combination is being studied in small ice-salt experiments. Previously, water solutions of brine and inhibitor were used to contact the steel coupons. Now the test solutions will be secured from melted ice-salt-water solutions. Chemical methods for the analysis of the constituents involved are being developed which will enable following the changing concentration of inhibitor during the course of the ice melting period.

It was felt that valuable information could be obtained on the corrosion behavior of rail joint preservatives by means of laboratory tests through an application of the techniques that have been successfully used in accelerated brine corrosion studies. Such information as may be derived from these tests could be correlated with service tests reported under Assignment 7. Accordingly, a modification of the accelerated brine corrosion test procedures was made to facilitate a three and six-months test which reproduced in part atmospheric conditions encountered in track service. The tests were performed on 11 proprietary compositions. Experimental details are described in Part 2 of Assignment 7. Certain features of the tests not included in Part 2 are worthy of comment. For example, during the course of the initial exposure to a temperature of 140 deg F, some of the preservatives softened and flowed away from the vertical surfaces. In some cases this was not too harmful and indicated that economies of application might be effected by using a thin coat initially; in other cases the loss was detrimental and led to serious corrosion. Fig. 1 demonstrates this behavior. The type of corrosion developed on the respective coupons is indicated in Fig. 2. Note the heavy incrustations on speci-

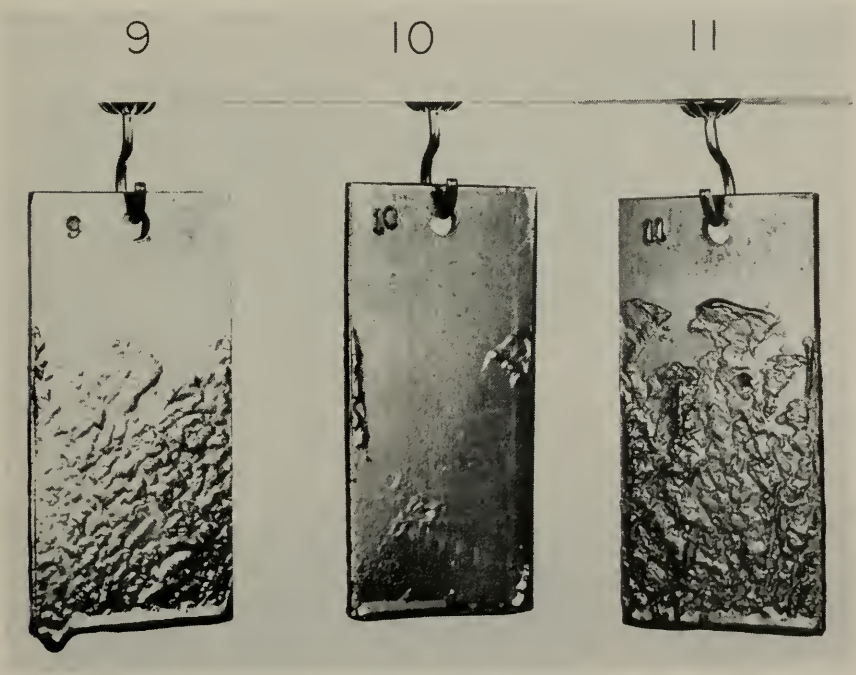


Fig. 1—Residual preservative after 6 hr at 140 deg F.

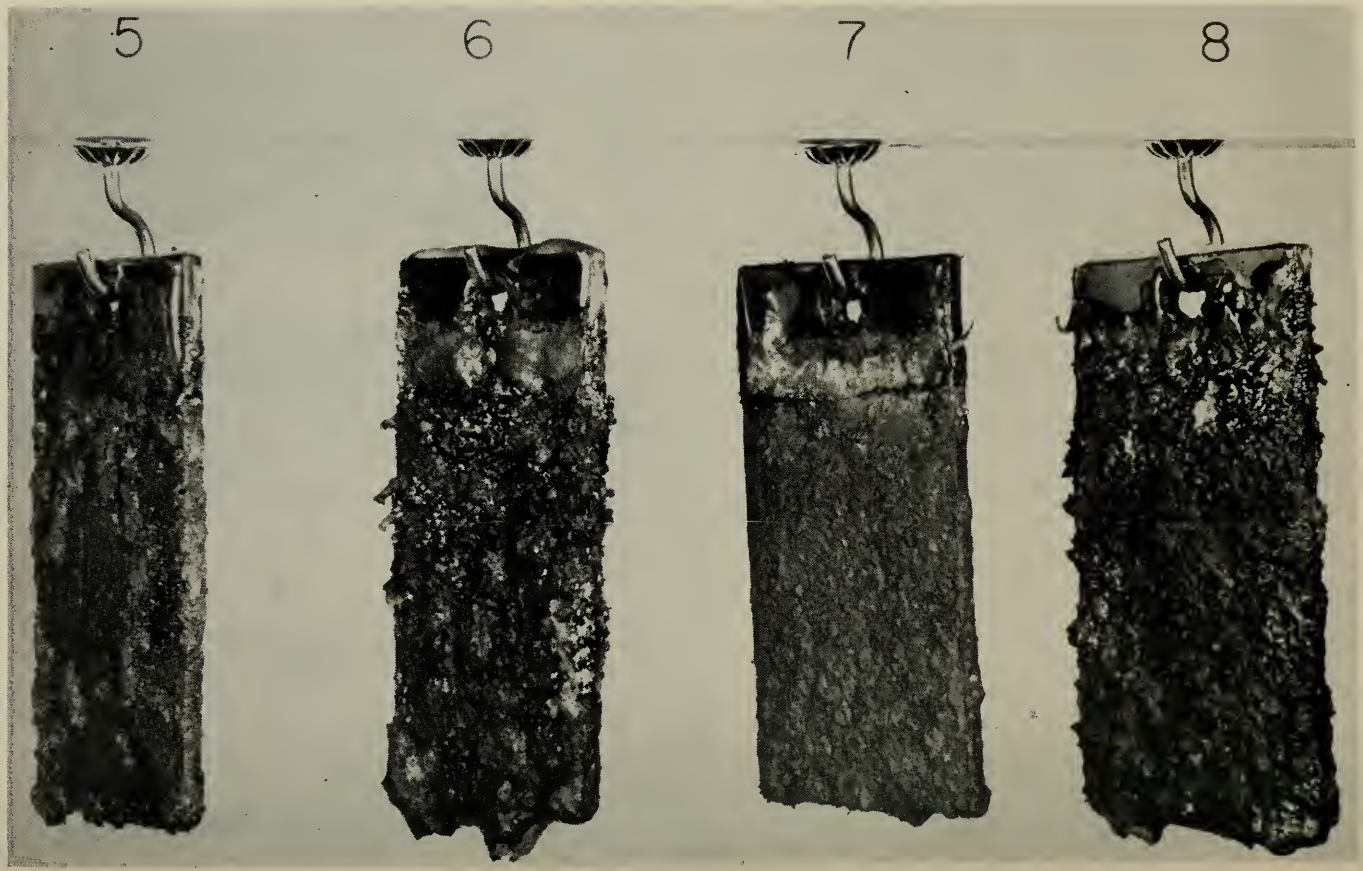


Fig. 2—Corroded specimens after 6 months of exposure.

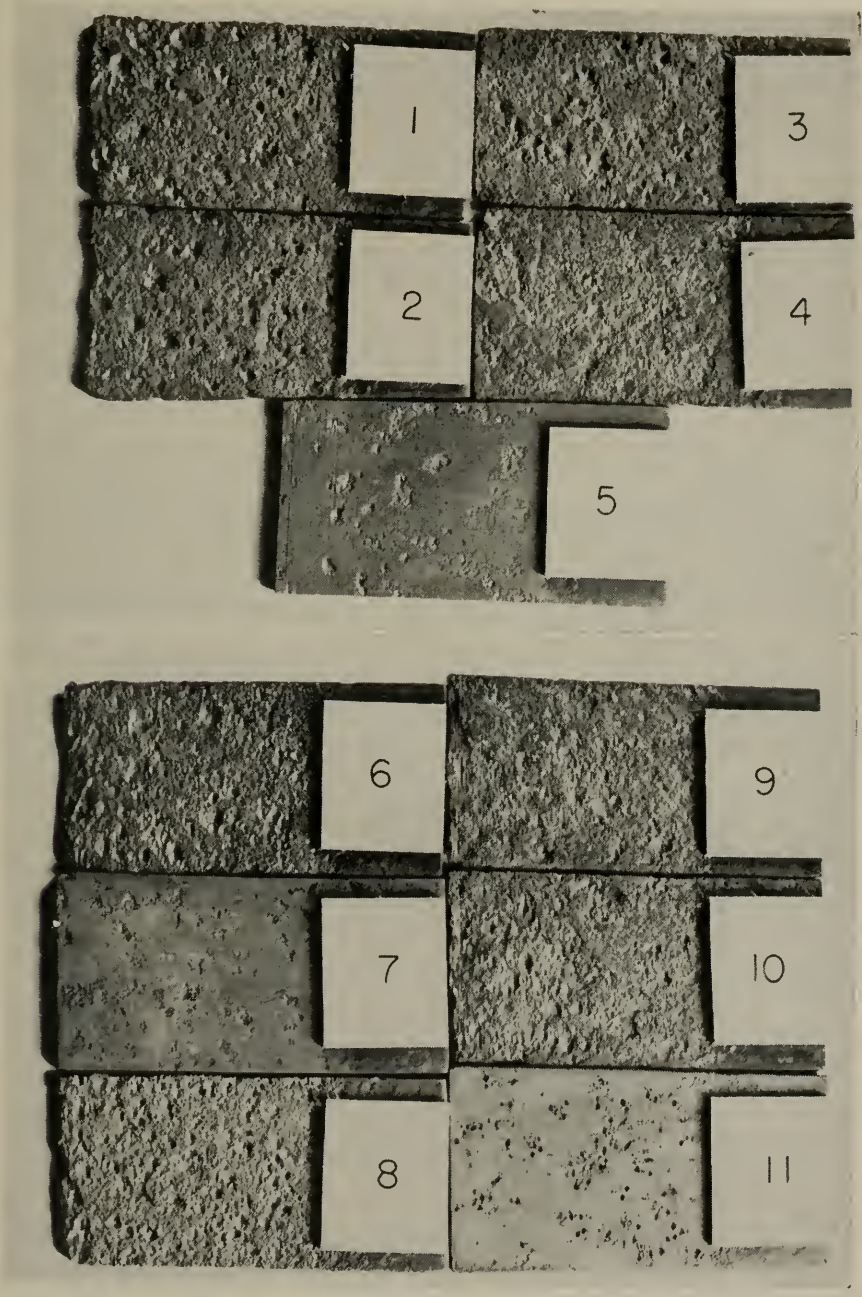


Fig. 3—Specimens with corrosion products removed.

mens 6 and 8 and the small amount of rust on specimens 5 and 7. Verification of these observations may be noted in Fig. 3.

The most characteristic feature in each instance is the presence of pits. Brine is a pit-former in contrast to many other types of corrosive agents, such as water or acids, wherein the corrosion is more general and covers the entire surface. Metals contain a variety of stresses and corrosion begins first in those areas suffering the greatest stress; thus, a close examination of specimens 1, 2, 3 and 8 reveals the same type of deep pits as is evidenced in specimen 11. Nevertheless, if the preservative is not efficient the remaining areas suffer corrosion also. This is shown by the numerous shallow craters surrounding the deep pits. Often the characteristic corrosion pattern can be altered by the presence of a corrosion inhibitor, and the broad shallow pits as shown in specimens 5 and 7 will develop instead of the deep pits.

Report on Assignment 5

Design of Tie Plates

Collaborating with Committees 3 and 4

V. C. Hanna (chairman, subcommittee), L. L. Adams, W. G. Arn, E. G. Brisbin, M. D. Carothers, W. E. Cornell, H. F. Fifield, J. W. Fulmer, A. E. Haywood, C. N. King, J. S. Parsons, J. A. Reed, R. D. Simpson, R. C. Slocomb, R. H. Timmins, M. J. Zeeman.

This progress report, submitted as information, covers the service tests of 7 designs of tie plates for the rail base width of 6 in.

Introduction

In November 1944, 7 designs of tie plates were installed in 22 panels of track laid with new creosoted ties, stone ballast, and 131 RE rail in Mile 326 of the single-track main line of the Cincinnati, New Orleans & Texas Pacific Railway (Southern Railway System), approximately 12 miles north of Chattanooga, Tenn. Eight of the test panels are located in a short 6-deg curve having 6-in elevation. Fourteen of the panels are on tangent track, and are equally divided as between oak and pine ties. Stress measurements under traffic have been made in all of the tie plate designs and have been reported. The service tests will develop information on plate cutting, possible permanent bending of the plates and gage widening. The results of the stress investigation were published in the Proceedings, Vol. 47, 1946, pags 491–514. The last progress report on these service tests was published in Vol. 55, 1954, pages 715–720.

From the beginning of these tests, gradual conversion from steam to diesel power was effected. On June 18, 1953, the line was completely dieselized. The test panels are located on a long stretch of level grade, and practically all trains traverse the 6-deg curve at or near the authorized speed of 45 mph. Because of the favorable operating conditions, it was not necessary to relay the rail on the curve until December 1952, after a service period of 8 years. The curve is protected by rail oilers in both directions. During the last service period, extending from June 1953 to April 1955, the gross tons of traffic increased from 187 to 228 million.

In recent years slag ballast has been used for maintaining the track. The test track was last surfaced with a power tamper in November 1953. No regaging has been done since the rail was relaid on the curve in December 1952.

This report covers the field measurements made in April 1955.

Tie Plate Penetration

Table 1 gives a summary of the plate cutting measurements for the 10.4-year service period. Data for the 6-deg curve are no longer subdivided as to anchor spikes vs no anchor spikes, because of the addition of spikes when the curve was regaged in June 1951. During the last service period there has been no acceleration in the rate of plate cutting on the test curve or tangent. The average depth of penetration for both rails of the curve ranged from 0.17 to 0.23 in. The latter figure is for the 12-in plates with 3 transverse ribs on the bottom, and includes cutting by the ribs. Using average values of tie abrasion for the 4 panels of 14-in tie plates, the plate cutting on the outer rail of the curve was 25 percent greater than on the inner rail. This reflects the effect of train operation being practically all above the equilibrium speed of 39 mph. The average tie abrasion in the same 4 panels of the curve with hardwood ties was 43 percent greater than in the corresponding panels with oak ties in tangent track. On tangent track the softwood ties were plate cut 34 percent deeper than the oak ties. In the tangent portion of the tests one-half of the plates in each panel of track, except the 12-in plates have 2 cut anchor spikes and the other half have line spikes only. Plate cutting on the softwood ties was about equal with or without anchor spikes. For the oak ties in tangent track, plate cutting with anchor spikes was 12 percent greater. The latter comparison may have been influenced by the variability of the oak ties as to softness and in the initial seating of the plates. These tests, as well as others, have shown that cut anchor spikes did not effect a reduction in plate cutting. The position of the mean centroid of tie plate loads, as calculated from the tie abrasion data for the 14-in plates on the curve, was $\frac{7}{8}$ in and $\frac{3}{8}$ in outward of the track from the center line of the rail base for the outer and inner rails, respectively.

The plate cutting on the curve has been moderate for 228 million gross tons of traffic because of favorable operating conditions. Tie abrasion in the tangent test panels has not been large because of the moderate speed limit of 45 mph due to being adjacent to the curve.

The tie plate penetration has not increased sufficiently to show the benefit of the larger tie plates. In this test the plate seating period was too short, and the variations caused by seating of the plates after taking the initial readings distorted the data. Because of the lack of damaging tie plate loads on the curve, this test will require several more years to develop good results with respect to plate length.

It is of interest to compare the rate of tie abrasion by the 13-in tie plates in the 6-deg curve with the 4-deg test curve on the Illinois Central Railroad near Curve, Tenn., where service tests are being conducted on several tie plate designs for the $5\frac{1}{2}$-in rail base width. No other tie plate length is common to both tests. On the 6-deg curve, tie abrasion by the 13-in plates for a period of 10.4 years with gross tonnage of 228 million was 0.191 in, equivalent to 0.084 in per 100 million gross tons. The 4-deg curve on the IC was last checked in April 1954, after a service period of 9.5 years with 176 million gross tons of traffic. Tie abrasion on the IC curve for the 13-in tie plates was 0.304 in, equal to 0.173 in per 100 million gross tons. Thus, the rate of plate cutting on the IC curve has been twice that of the 6-deg curve. This difference in the rate of tie wear was the result of many factors, of which three are perhaps the most important. The maximum speed on both curves is about the same, or 45 mph. The 4-deg curve has 4-in elevation, and an appreciable portion of the tonnage operates below the balanced speed, with some trains running as slow as 20 mph. There was very little traffic below the balanced speed on the 6-deg curve. During the test periods most of the tonnage on the IC

TABLE 1. - SERVICE TEST OF MECHANICAL WEAR OF TIPS WITH SEVEN DESIGNS OF TIE PLATES FOR 131 RE RAIL ON C.N.O.&T.P. Ry. MILE 326 (SOUTHERN RY. SYSTEM), NEAR CHATTANOOGA; TENN.

Tie Plate Design No.	Tie Plate Dimensions (in.)	Rail Seat	Tie Plate Penetration from Nov. 1944 to April 1955 in 0.001 in, 228 million gross tons of traffic											
			2 Anchor Cut Spikes					No Anchor Spikes					All Tie Plates	
			Inner or East Rail		Outer or West Rail		Both Rails	Inner or East Rail		Outer or West Rail		Both Rails	Both Rails	
			Field End	Gage End	Gage End	Field End	Mean	Field End	Gage End	Gage End	Field End	Mean	Mean	Percent Loose Plates
6° Curve - Creosoted Oak Ties														
831	7 1/2 x 14 3/4 x 31/32	Rolled Circular	162	159	181	231	183	—	—	—	—	—	183	58
831-Z	7 1/2 x 14 x 31/32	Rolled Circular	172	159	162	248	185	—	—	—	—	—	185	66
831-Y	7 1/2 x 14 x 7/8	Rolled Circular	154	155	163	237	177	—	—	—	—	—	177	51
831-X	7 1/2 x 14 x 3/4	Rolled Circular	159	161	160	235	179	—	—	—	—	—	179	38
420	7 3/4 x 14 x 7/8	Flat	147	171	138	252	177	—	—	—	—	—	177	58
Plan5	7 3/4 x 13 x 27/32	Rolled Circular	175	167	183	238	191	—	—	—	—	—	191	44
405	8 x 12 x 3/4	Rolled Circular	—	—	—	—	—	132	159	144	228	166	166	46
*405-A	8 x 12 x 3/4	Rolled Circular	—	—	—	—	—	155	254	219	277	226	226	45
Tangent - Creosoted Oak Ties														
831	7 1/2 x 14 3/4 x 31/32	Rolled Circular	135	160	137	143	144	126	138	121	141	132	138	72
831-Z	7 1/2 x 14 x 31/32	Rolled Circular	133	127	114	146	130	131	129	116	138	128	129	79
831-Y	7 1/2 x 14 x 7/8	Rolled Circular	127	124	116	145	128	108	99	102	126	109	118	68
831-X	7 1/2 x 14 x 3/4	Rolled Circular	141	137	132	134	136	132	114	109	143	124	130	60
420	7 3/4 x 14 x 7/8	Flat	129	145	126	152	138	109	119	108	132	117	128	72
Plan 5	7 3/4 x 13 x 27/32	Rolled Circular	127	117	136	127	127	124	101	98	118	110	118	84
405	8 x 12 x 3/4	Rolled Circular	—	—	—	—	—	124	131	127	122	126	126	82
Tangent - Creosoted Pine Ties														
831	7 1/2 x 14 3/4 x 31/32	Rolled Circular	162	239	244	145	198	160	247	206	167	195	196	79
831-Z	7 1/2 x 14 x 31/32	Rolled Circular	107	245	196	142	172	121	217	192	154	171	172	82
831-Y	7 1/2 x 14 x 7/8	Rolled Circular	163	252	197	145	189	158	232	191	174	189	189	67
831-X	7 1/2 x 14 x 3/4	Rolled Circular	123	177	191	145	159	115	185	164	157	155	157	79
420	7 3/4 x 14 x 7/8	Flat	133	151	162	157	151	139	202	150	163	164	157	83
Plan 5	7 3/4 x 13 x 27/32	Rolled Circular	147	181	189	159	169	128	180	169	173	162	166	71
405	8 x 12 x 3/4	Rolled Circular	—	—	—	—	—	114	173	205	148	160	160	75

Note: All tie plates have 3/8 in eccentricity, except design 831 has 1/2 in and Plan 5, 1/4 in.
All tie plates have flat bottom, except design 405-A has three transverse ribs.
*Penetration measurements include cutting of the ribs into the ties.
The 8-in x 12-in tie plates were not punched for anchor spikes.

was hauled by steam power, while on the 6-deg curve diesels hauled more than one-half the tonnage. The weight of rail was a significant factor, this being 112 RE on the 4-deg curve and 131 RE on the 6-deg curve.

Tie Plate Bending

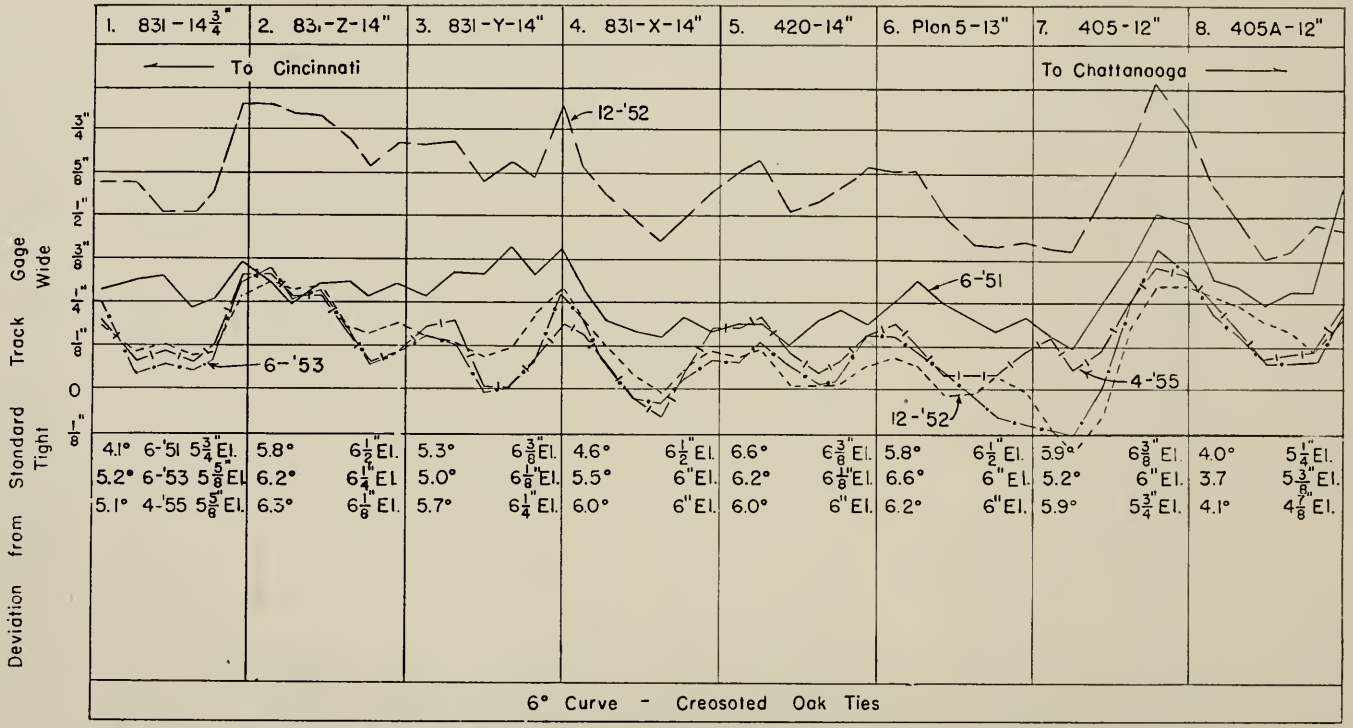
The measurements of tie plate deflection taken in April 1955 indicated that no permanent bending of the tie plates had occurred. The 831-X design of tie plate is 1/8 in thinner than the 14-in tie plate covered by AREA Plan No. 12. There has been no bending of the 831-X plates. It is assumed that the underplate area on the wood has not been worn sufficiently to a concave upward surface to cause permanent bending. There was no evidence along the track of severe corrosion of the tie plates. The test has not been of sufficient length to determine if the thinnest plate (for its length) will become permanently bent. In the tie plate design test on the Illinois Central, it was found that a few of the 11-in tie plates, having a thickness of 1/8 in less than the plate shown in AREA Plan No. 4, had been bent.

Gage of Track

Figs. 1 and 2 show the record of the track gage for the curve since regaging in June 1951 and for the tangent test panels since the inception of the test. The gage on the 6-deg curve (Fig. 1) has changed little since the rail relay. The average gage of the curve is 1/8 in wide, or about the same as after the rail relay. There had been practically no gage widening due to rail wear at the gaging level, 5/8 in below the top of rail head. The curve was in good line and cross level when the last measurements were taken. The track gage of the two stretches on tangent had a little more irregularity, but the average gage for each stretch was about the same as in November 1944.

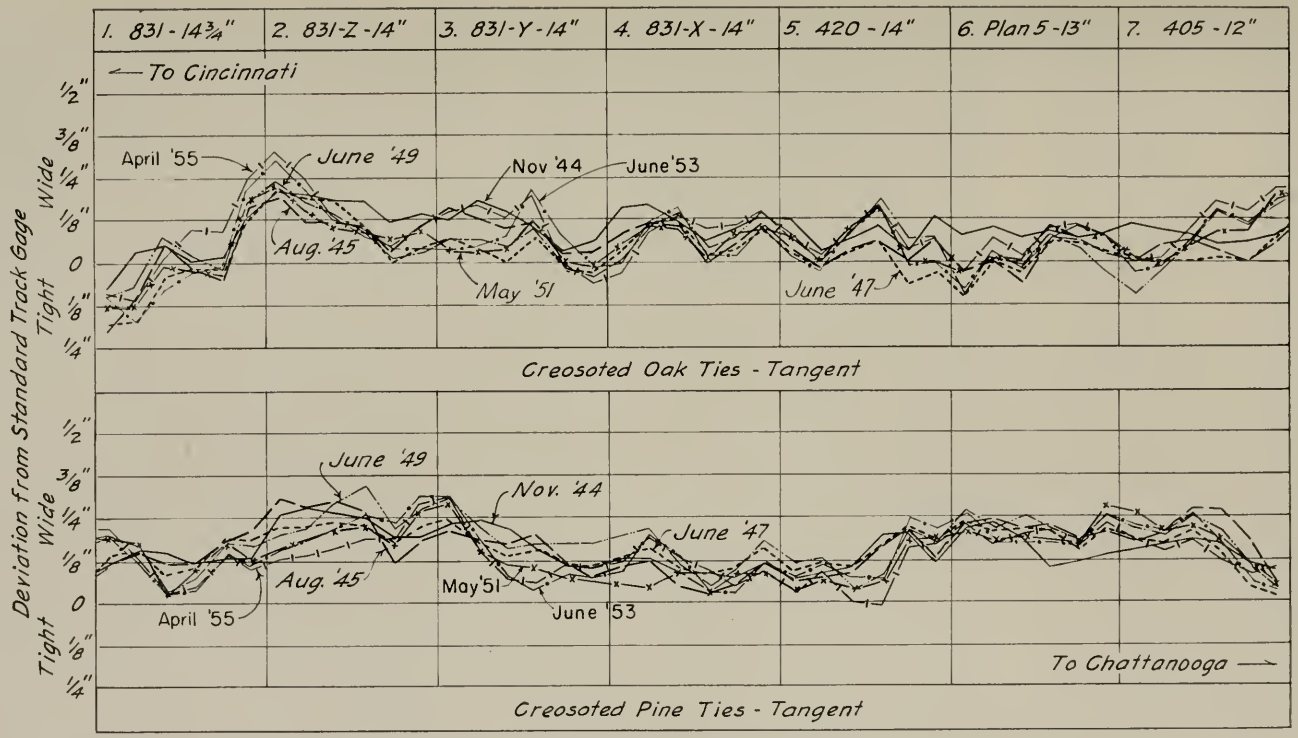
An analysis of the causes of gage widening during this service test indicates that there has been no significant outward cant of the inner rail due to unequal plate cutting. Because the depth of plate cutting on the outer rail has been moderate, the gage widening caused by unequal plate cutting amounted to only 0.04 to 0.05 in. The 405–A tie plates with ribbed bottom have held gage widening to the smallest amount. This panel of track had the advantage of being on the spiral with an average curvature of 4.1 deg, and also had less wear on the outer rail than in the other sections. For a total gage widening of 0.41 in, 83 percent was due to rail wear, 10 percent due to unequal plate cutting, and only 7 percent due to horizontal plate movement. A good comparison of the 12-in plates with and without the ribs cannot be made because of a short stretch of wide gage that developed in the panel of track without the ribs. Obviously, the difference in the quality of the ties and alinement of the curve in those two panels were sufficient to spoil the comparison. Both panels of 12-in plates had the same spiking. The average values for the 4 panels of 14-in tie plates with flat bottoms will be more representative of the performance of tie plates without transverse ribs. For a total gage widening of 0.83 in, 66 percent was due to rail wear, 5 percent due to unequal plate cutting, and 29 percent due to horizontal plate movement. The 12-in ribbed-bottom plates with track curvature of 4.1 deg had only 7 percent of the total gage widening chargeable to horizontal plate movement on the ties, as compared with 29 percent for the 14-in plates in track with curvature of about 6 deg.

In the test on the 4-deg curve of the Illinois Central near Curve (Vol. 56, 1955, page 832), the 11-in and 13-in tie plates on oak ties had a horizontal plate movement of about 40 percent of the total gage widening. Although the operating conditions are quite



All track panels are 39 ft. in length and divided at the joints in outer rail.
Each tie plate has 3 cut spikes for line and 2 for anchors, except panels 7 and 8 have 4 line spikes and no anchors.
——— After regaging in 1951, ——— Before relaying rail in 1952, – – – – After relaying rail in 1952.
All tie plates have flat bottoms, except design 405A has three transverse ribs.

Fig. 1. - Gage, Curvature and Elevation, of Each Panel of Test Track on the 6° Curve, C.N.O. & T.P. Ry., Mile 326



Each Tie Plate has 2 Line Spikes and, in addition, 2 Cut Spikes for Anchors in the North Half of Each Panel of Track, except in Panel 7. Panels are divided at the joints in the west rail.

Fig. 2. - Gage of Each Panel of Test Track on Tangent, C.N.O. & T.P. Ry., Mile 326.

different on the 4-deg and 6-deg curves, it is reasonable to assume there was some reduction in plate movement on the 6-deg curve because of having 131 RE rail vs 112 lb rail on the 4-deg curve.

Reinstallation of Special Tie Plates for Curves

As stated in the last report of this subcommittee (Vol. 56, 1955, page 824), the service test of the 8 by 15 by 1-in tie plates with 1¼-in eccentricity in the inner rail of a 4-deg curve with softwood ties and 112-lb rail on the Illinois Central near Curve was terminated. These tie plates are similar to AREA Plan No. 20, except that they were made of 1-in uniform thickness plates with a milled rail seat and bars welded in place for the shoulders.

For reinstallation it was desired to select a sharp curve with 100 percent diesel operation. The IC kindly suggested a location on the single-track line of the Iowa Division, west of Dubuque, Ia. The location chosen is the 6-deg curve at Mile Post W–188. This curve is on a long hill ascending westward, and has an 0.85 percent grade where the plates were reinstalled. The curve has 4½-in elevation and is restricted to 40 mph for passenger trains and 35 mph for freight trains. Some of the heavy westward trains are said to drop down to speeds of 20 to 25 mph. It is, therefore, expected that some of the slower trains will operate on track as much as 2¾ in below the elevation for the equilibrium speed of 34 mph. To develop the full benefits of the special plates on the inner rail, it is necessary to have some traffic operate below the balanced speed, such as was the case in the original location. The annual traffic carried by the 6-deg test curve is approximately 16 million gross tons.

During the first half of August 1955, the test was installed and the curve was given a general surfacing and lining. The construction consists of 4 test sections of 2 track panels each, with twenty-four 7 by 9-in by 8-ft 6-in sawed creosoted oak ties per panel. Three of the sections have the special 15-in plates on the inner rail and the 13-in AREA Plan No. 7 plates on the outer rail. Racor studs, tie plate lock spikes, and cut spikes are each used as hold-down fastenings (2 per plate) in both rails of 2 panels of track. The fourth section, for controls, has 13-in tie plates under both rails and cut spike construction. Because the tie plates are of 1-in uniform thickness, except for the canted rail seat, the Racor studs furnished are ½ in longer than standard. The studs were driven with a dual pneumatic hammer in holes drilled to ⅝ in diameter. The lock spikes are of the 7-in overall length, as in the AAR–L&N test. Each joint with new ties is supported with three ties. In addition to four cut spikes per plate, the IC construction includes a special rail brace, fastened with three screw spikes and placed against the field side of both rails on every fourth tie. The braces were omitted from the earlier AAR–IC test. The test panels are located partly on a hillside and embankment, and on reasonably stable roadbed. The track is ballasted with chats having a maximum size of about ½ in.

The field measurements will consist of tie abrasion, gage of track, elevation and curvature of each panel of track. These measurements, except for tie abrasion, will be extended to include two panels of the IC construction, with new ties, at each end of the stretch.

Conclusions

A longer service period on the CNO&TP test will be required to develop the advantage of the longer tie plates. None of the tie plates had become permanently bent. Analysis of the gage widening on the curve during the entire service period indicates that the part attributed to horizontal tie plate movement was smaller with the ribbed-bottom

plates than with the flat-bottom design. Previous reports on this test have shown that the ribbed-bottom plates held gage as well as the flat-bottom plates with at least one less cut spike.

Acknowledgement

The Association gratefully acknowledges the splendid cooperation and assistance rendered by the Southern Railway and the Illinois Central, and is indebted to the suppliers for their valuable assistance.

Report on Assignment 6

Hold-Down Fastenings for Tie-Plates, Including Pads Under Plates; Their Effect on Tie Wear

Collaborating with Committee 3

J. S. Parsons (chairman, subcommittee), L. L. Adams, H. D. Ashley, F. J. Bishop, M. C. Bitner, J. C. Brennan, E. W. Caruthers, H. B. Christianson, C. A. Colpitts, W. E. Cornell, E. D. Cowlin, F. W. Creedle, R. G. Garland, V. C. Hanna, L. H. Jentoft, T. R. Klingel, M. P. Oviatt, J. M. Rankin, J. A. Reed, M. K. Ruppert, T. R. Snodgrass, R. E. Tew.

This report, presented as information, gives the results of the annual inspection of the service tests of hold-down fastenings, tie pads, etc., (1) on the Louisville & Nashville Railroad, and (2) for the tie plate fastenings in the tests being conducted by the Illinois Central Railroad.

This investigation is being conducted by the AAR research staff under the general direction of G. M. Magee, director of engineering research. H. E. Durham, research engineer track, is in direct charge of this assignment and is being assisted by A. D. Van Sant, assistant research engineer track, and other members of his staff.

TESTS ON THE LOUISVILLE & NASHVILLE

Introduction

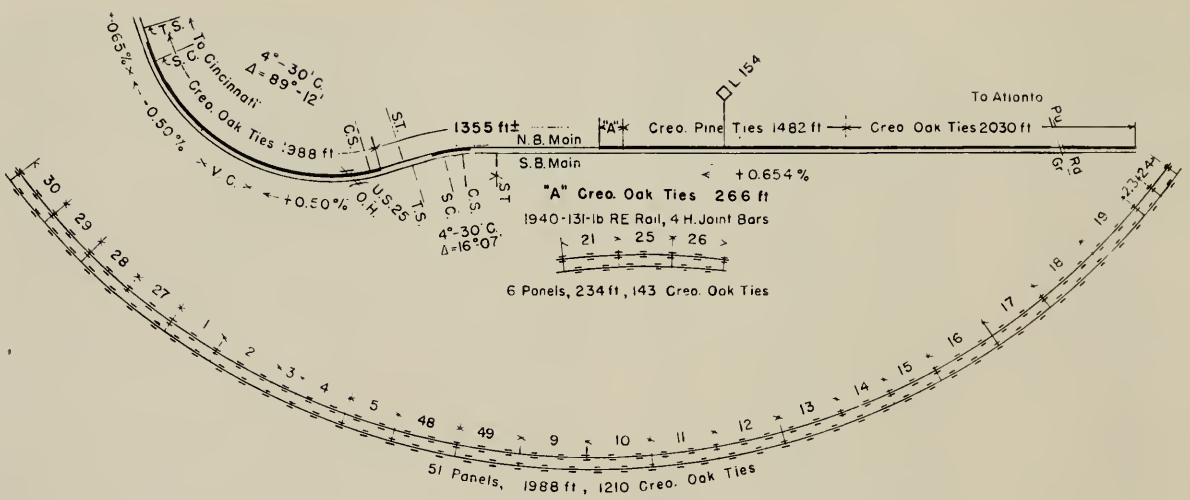
These tests were begun in 1947* for the primary purpose of developing information for determining the most effective and economical methods for increasing the service life of ties by minimizing plate cutting and reducing the frequency of regaging and readzing curves by the use of special hold-down fastenings, tie pads, etc. The tests are located in the northward main of the L&N in the vicinity of London and East Bernstadt, Ky., where the traffic density is in excess of 20 million gross tons, consisting largely of loaded coal cars. Most of the tonnage is now hauled by diesel power. The subcommittee's last report was published in the Proceedings, Vol. 56, 1955, pages 836–859.

Four new test sections were installed in the 5-deg test curve at East Bernstadt in 1955.

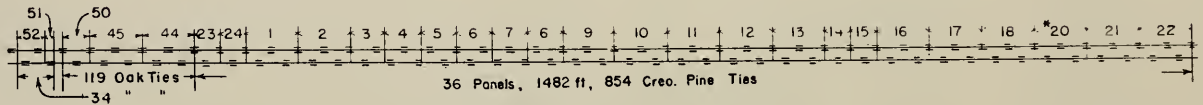
A general inspection of all the test installations was made in June 1955 by the AAR research staff. The subcommittee and its guests attended the inspection on June 22, 1955, when the pads and underplate coatings were examined by removal of the tie plates and pads. This report will include a description of the additional test sections and the more important results of the visual inspections.

* See Proceedings, Vol. 50, 1949, pp. 595–623, for description of original installations.

(Text continued on page 711)



High Rail 131-lb RE laid in 1940, Low Rail S.H. 131-lb RE laid in 1947, 4 Hole Joint Bars



131-lb RE Rail laid in 1944, 6 Hole Joint Bars

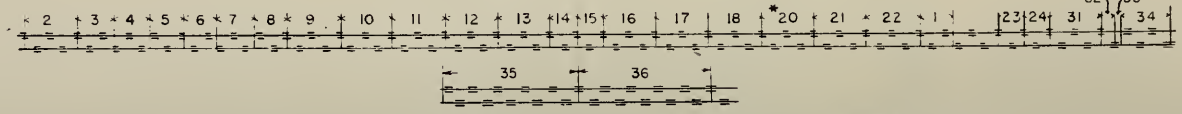


Fig. 1.- Plan of Test Track

TABLE 1. DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 1

Section No.	No. of Test Ties: Creo. Oak Curve	Creo. Oak Tang.	Pine Tang.	Total	Tie Plate Length in	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate, Tie Pads and Coatings (131-lb RE Rail)
1							Coatings and adhesives - no anchor spikes - subdivided as follows:
1.1	11	6	12	29	13	9-47	Beckosol No. 40. Hot paddle coat applied to bottom of tie plate
1.2	9	9	9	27	13	9-47	AREA Specification Waterproofing Asphalt applied as in subsection 1.1
1.3	0	4	6	10	13	9-47	CASCO Flexible Cement MT-442 applied to tie plate and tie in the field
1.4	3	3	6	12	13	9-47	MT-442 Cement applied to tie plate as a primer and CASCOPHEN RS-216 applied to tie plate and tie in the field
1.5	9	9	9	27	13	9-47	Same as subsection 1.4 except the tie plates were cemented to the ties before creosoting
1.6	2	0	0	2	13	9-47	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating, designated No. 52
1.7	2	0	0	2	13	9-47	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating modified to further reduce flow, designated No. 53
1.8	2	0	0	2	13	9-47	Same as subsection 1.7, except the asphalt was formed around brass screening, designated No. 54
1.9	2	0	0	2	13	9-47	Same as subsection 1.7, except the asphalt was formed around 1/4 in mesh galvanized screening, designated No. 55
1.10	6	0	0	6	13	8-48	Solvated Sealz Coating. Heavy brush coat applied to tie and tie plate
2	59	47	48	154	13	8-47	No anchor spikes (Rubber line spike cushions were applied to the north 24 ties of each tangent section 12-49)
3	0	31	32	63	13	8-47	1-ply duck pad with asphalt coating (Made by Bird & Son), no anchor spikes
3	(b)24	0	0	24	13	6-52	Bird improved fiber-rubber pads (1-ply duck pads were in service on the same ties from 8-47 to 6-52)
4	(b)27	0	0	27	13	6-52	Bird vinyl pads on N. 27 ties (5-ply duck-felt pads were in service on the same ties from 8-47 to 6-52)
4	0	32	32	64	13	8-47	5-ply Bird duck-felt pads, no anchor spikes
4	20	0	0	20	13	8-48	5-ply Bird duck-burlap pads on the south 20 ties of curve test section (Duck-felt pads in test 8-47 to 8-48), no anchor spikes
5	20	0	0	20	13	8-48	7-ply Bird duck-burlap pads on the north 20 ties of curve test section (Duck-felt pads in test 8-47 to 8-48), no anchor spikes
5	29	31	32	92	13	8-47	7-ply Bird duck-felt pads, no anchor spikes
6	0	32	32	64	13	8-47	2 each of cut spikes for line and Racor Studs for anchors, (Changed from 2 Racor Drive Tight line spikes 12-49)
7*	0	32	32	64	13	8-47	2 each of Racor Drive Tight (Sandberg) line and anchor spikes. (Anchor spikes replaced 11-48)
8*	0	31	32	63	13	8-47	2 each of cut spikes for line and Racor Drive Tight (Sandberg) for anchors. (Anchor spikes replaced 11-48)
9	59	48	48	155	13	8-47	2 each of cut spikes for line and anchors. (Rubber anchor spike cushions were applied to the north 10 pine ties 12-49)
10	59	47	49	155	13	8-47	2 cut spikes for line and 2 round head cut spikes with single coil spring washers for anchors
11	59	47	47	153	13	8-47	2 cut spikes for line and 2 round head Dowel Studs with double coil helical spring washers for anchors
12	57	48	48	153	13	8-47	2 cut spikes for line and 2 Oliver Hold-Down Drive Spikes with double coil helical spring washers for anchors
12	2	0	0	2	13	8-47	2 cut spikes for line and 2 cone neck Oliver Hold-Down Drive Spikes without spring washers for anchors
13	47	47	47	141	13	8-47	2 cut spikes for line and 2 Elastic Spikes of design No. 93 for anchors
13	12	0	0	12	13	8-47	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors (North 12 ties)
14	47	24	24	95	13	8-47	2 cut spikes for line and 2 - 3/4 in thru bolts Applied in the field
15	48	24	24	96	13	9-47	with single coil washers for anchors Applied in shop under load
16(a)	60	47	48	155	13	8-47	2 cut spikes for line and 2 screw spikes with double coil washers for anchors
17	60	47	47	154	13	8-47	2 AAR spring rail clips and screw spikes for line and anchor spikes on tangent plus 2 cut spikes for line on the curve (PRR standard 14-3/4 in tie plates cut to a 13-in. length with 1/4 in eccentricity)
18	58	48	48	154	13	8-47	No anchor spikes. Erie single shoulder tie plate with diamond bottom and zero eccentricity
19(a)	59	0	0	59	13	8-47	2 cut spikes for line and 2 screw spikes with double coil washers and above Erie RR tie plate
21	0	47	47	94	13	8-47	Fabco tie pads, 1/4 in thick, uncoated, no anchor spikes
21	47	0	0	47	13	8-48	Fabco tie pads, 1/4 in. thick, uncoated, no anchor spikes

(Continued on next page)

* The supplier of the special fastenings used in sections 7 and 8 requested discontinuance of these sections in 1953.

TABLE 1. (CONCL.) DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 1

Section No.	No. of Test Ties				Tie Plate Length in	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate, Tie Pads and Coatings (131-lb. RE Rail)
	Creo. Oak		Pine				
	Curve	Tang.	Tang.	Total			
22	0	48	48	96	13	8-47	2 cut spikes for line and 2 Oliver Tie Plate Drive Spikes with single coil spring washers for anchors
23	24	24	23	71	14	9-47	L.& N. standard construction with 2 each of cut spikes for line and anchors
24	24	24	24	72	14	9-47	Same as section 23, except a Rails Co. compression clip was applied to alternate tie plates
25	47	0	0	47	13	8-48	Johns-Manville, uncoated, laminated rubber-asbestos tie pads; 1/8 in thick in north panel, 1/4 in thick in south panel, no anchor spikes
26	49	0	0	49	13	8-48	DL&W D.S. diamond bottom tie plate with 1/2 in eccentricity, 2 cut spikes for line and 1 anchor only
27	48	0	0	48	SH 13	10-48	Burkart fiber pads, no anchor spikes
28	48	0	0	48	SH 13	9-49	Western Felt Works wool felt pads, 1/4 in thick, no anchor spikes
29	48	0	0	48	SH 13	9-49	Bird fiber-rubber pads, 1/4 in thick, coated, no anchor spikes
30	48	0	0	48	SH 11	9-49	Bird 5-ply duck-burlap pads. SH 11 in plates were cut from 13 in. Plan 5B plates, no anchor spikes
31	0	48	0	48	14	8-49	G&H Controls No-Creep rail anchors on alternate tie plates. 2 cut line spikes on unanchored ties, 1 cut line spike and 2 Oliver Tie Plate Drive Spikes for anchors on anchored ties
32	0	12	0	12	14	9-49	Farbertite. Paddle coat applied to adzed surface and bottom of tie plate, no anchor spikes
33	0	5	0	5	14	9-49	Tie plates cemented to ties as in section 1.5 but under ideal conditions, no anchor spikes
34	0	48	0	48	14	9-49	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors. Asphalt roofing paint brushed on adzed surfaces of south 24 ties
35	0	120	0	120	SH 13	7-50	Coating of Koppers No. 16 Sealing Compound with covering of 1/4 in washed gravel on alternate new ties, 2 each of cut line and anchor spikes
36	0	118	0	118	SH 13	7-50	Coating of Koppers No. 16 Sealing Compound with covering of 1/4 in washed gravel on existing ties, 2 each of cut line and anchor spikes
44	0	48	0	48	12 7/16	11-50	Dayton Rubber Co's. cast steel tie plates with raised rubber insert pads on new ties, 2 each of cut line and anchor spikes
45	0	47	0	47	12 7/16	11-50	Same as section 44 except that existing ties in track were used
48	58	0	0	58	14	8-52	Racor coated tie pads with 2 cut line spikes and 2 Racor studs for anchors
49	60	0	0	60	14	8-52	2 cut spikes for line. 3 Racor studs as anchors on N. 30 ties and 4 on S. 30 ties
50	0	24	0	24	14	7-53	Paddle coat of "Anker Seel" applied to adzed surfaces, 2 each of cut line and anchor spikes
51	0	10	0	10	14	7-53	2 cut spikes for line and 2 creo. hardwood Nordberg pegs for anchors
52	0	24	0	24	14	8-53	Paddle coat of Protek-Tie applied to adzed surfaces, 2 each of cut line and anchor spikes
	1,353	1,341	854	3,548			Totals

Notes: All of the new 13-in tie plates, except as noted above, were of the AREA Plan 5B (Modified) design with flat rail seat. Second hand (SH) 13-in tie plates were of the Plan 5B Design with rolled circular crown. All of the 14-in. tie plates placed prior to 1949 were of the AREA Plan 6B design and subsequent installations were of the current design, AREA Plan 12. All tie plates have flat bottom except as noted above.
In the sections on the two 4-deg. 30 min. curves where no anchor spikes were provided, 4 cut spikes were used.
(a). In the north half of each portion of the test sections the double coil Helical (experimental) spring washer was used and in the south half the double coil Thackery washer was used. Prior to 1952, all of the above tie pads were placed without anchor spikes, except in sections 44 and 45. (b). These pads have 2 each of cut line and anchor spikes.
Section 20 with 2 Thompson rail and tie plate clamps has been excluded from this table and discontinued upon request by the sponsor.
Each portion of each test section has an oval tag on the north tie showing the section number, and every tenth tie from the north has a smaller tag showing the tie number.

Additions in 1955

Four short test sections with new creosoted oak ties, 14-in flat-bottom tie plates and 2 each of cut line and anchor spikes were installed in the 5-deg test curve, June 23, 1955. Sections 53 and 54 were placed on the sharp portion of the north spiral, and sections 55 and 56 were located partly on and off the south spiral. Three of the sections are 1½ rails long, while the other is only ½ rail long. The location and a brief description of the additional sections are given in Fig. 2 and Table 2. All of the tie pads were pre-punched for two staggered line spikes to facilitate matching the tie plate punching with the ½-in diameter prebored holes in the ties.

Section 53

This section consists of 13 ties with 8 by 14-in Nox-Rust tie seals placed on the adzed surfaces. The tie seals were manufactured by the Nox-Rust Division, Daubert Chemical Company, and furnished by the Champion Transportation Sales, Inc., both of Chicago. The seals are premolded sheets of asphaltic material, approximately ⅛ in thick, and have been developed for use under tie plates. The material is similar to Protek-Tie (applied in section 52 in 1953), except that it is modified to be a solid instead of a liquid for rapid use in connection with rail relay work. The seals are said to contain several chemical rust inhibitors to retard corrosion of the spikes and tie plates because of the deleterious effect of the corrosion products on the wood fibers. The seals are priced at $0.10 each and installation is recommended for atmospheric temperatures ranging from 50 deg to 110 deg F. At colder temperatures the asphalt becomes brittle and the sheets will break into pieces when driving spikes through them. On the day of installation the temperature was about 80 deg F, and a light shower fell. Under these conditions the sheets were squeezing into the tie plate holes and filling them better than was the case with the Protek-Tie (a liquid) in section 52 (Vol. 55, page 726). Mastics, smears or sheets of asphalt used under tie plates do not eliminate tie abrasion. However, during their effective life (which is quite short in relation to a tie life of 25 to 30 years) it is possible to reduce plate cutting to a minor extent by keeping sand and other abrasives and water from getting under the plates; that is, by eliminating two accelerators of tie abrasion.

After 6½ weeks of service the asphaltic sheets had filled about 75 percent of the vacant spike holes in the tie plates. The material had squeezed up and around about one-half of the cut spikes, this tendency being greater at the line spikes. In general, the material had a greater tendency to squeeze out in sheets than to form protective ridges along the plate perimeter.

Section 54

This section has 36 ties with 8 by 14-in natural rubber pads, ¼ in thick, uncoated, furnished by the Railroad Rubber Products, Inc., at Ashtabula, Ohio. On the south 10 ties of this section, a heavy brush coat of Super Seal, a liquid rubber sealant with a Stoddard solvent, was applied to the adzed surfaces about 20 min before setting the tie plates in place. The coating had not set firmly. It is said that the liquid rubber, when dry, forms a medium hard protective coating, but it is not claimed to keep the pad cemented to the tie. The liquid rubber seal costs approximately $0.14 per adzed surface. There were no splits in the pads at the anchor spikes after 6½ weeks of service.

This installation, together with the ⅛-in thick Dunne molded natural rubber pads placed in section 42, July 1950, will develop information on the economy of the 2 thick-

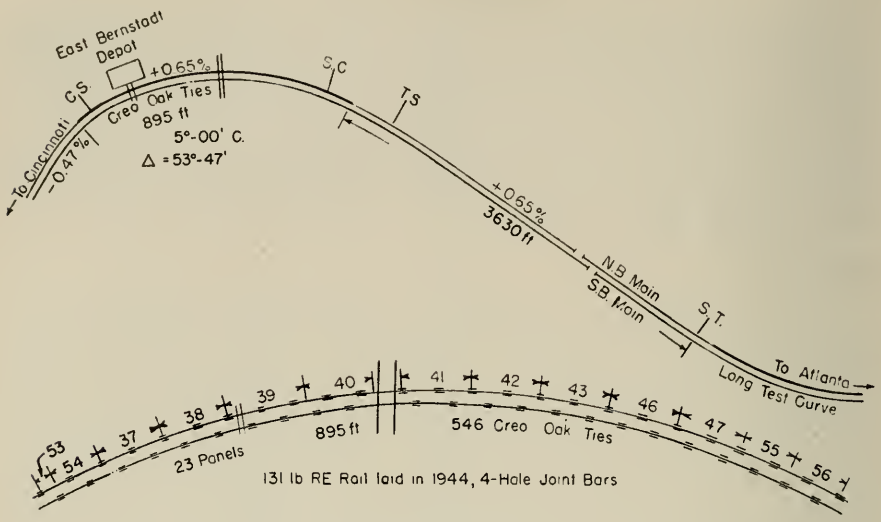


Fig. 2.- Plan of Test Track

TABLE 2. DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 2.

Section No.	No. of Creo. Oak Ties	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate and Tie Pad APEA Flat Bottom 14-in Tie Plates, 131-lb PE Rail
37	48	7-50	2 each of cut spikes for line and anchors
38	48	6-52	Achuff sisal fiber pads, uncoated (Original Pads placed 7-50, third set installed 6-52)
39	22	7-50	Johns-Manville rubber-vegetable and asbestos fiber pads, uncoated (North 22 ties)
39	22	11-51	Johns-Manville rubber-comp. pads with coating on the bottom side, replacing original J.M. pads placed 7-50
40	48	7-50	Taylor Fibre Co's. rubber-vulcanized fiber laminated pads
41	23	7-50	Fabco pads, uncoated (North 23 ties)
41	12	7-51	Fabco pads with an oxidized asphalt coating compound on the bottom side. (These pads replaced pads placed in 7-50 with Baker's K-2 cement on the bottom side.)
41	12	7-50	Fabco pads coated on both sides with Baker's S-72 cement (South 12 ties)
42	48	7-50	Dunne Rubber Co's. molded rubber pad, 1/8 in thick, uncoated
43	47	7-50	2 each of cut spikes for line and Racor Studs for anchors
46	24	11-51	Racor rubber-fiber pad, uncoated
46	25	11-51	Racor rubber-fiber pad with asphaltic coating on both sides
47	48	6-52	Burkart fiber pads, coated on bottom side
53	13	6-55	Nox-Rust tie seals under tie plates (solid sheet of Protek-Tie, approx. 1/8-in thick)
54	36	6-55	Railroad Rubber Products natural rubber pads 1/4-in thick, uncoated. The adzed surfaces of the south 10 ties were coated with Super Seal, a liquid rubber sealant.
55	35	6-55	Johns-Manville fiber-rubber pads, 1/4-in thick, bottom coated
56	36	6-55	Fabco pads, bottom coated, 1/4-in thick on north 18 ties and 1/8-in thick on south 18 ties
	547		Total

Notes: All pad sections have 2 each of cut line and anchor spikes. All sections, except Nos. 46 and 47, were installed with new AREA Plan 12 tie plates. Sections 46 and 47 have SH 14-in APEA Plan 6B tie plates. Plan 6B was withdrawn from the Manual in 1948.
Each test section has an oval tag on the north tie showing the section number, and every tenth tie from the north has a smaller tag showing the tie number.

nesses of rubber pads. It is not to be implied that, because the ⅛-in rubber pad is included in these tests, it is considered adequate for a good service life at minimum cost per pad year. However, from results of its performance, the minimum economical thickness can be determined.

Section 55

Johns–Manville 1954 formulation of ¼-in thick fiber-rubber tie pads, bottom coated, were installed on 35 ties. The pads had dimensions of 7⅝ by 13⅞ in, and the coating was made of a catalytic asphalt compound. After 6½ weeks of service, there were no pads split at the anchor spikes, and the coating appeared to have a tendency to squeeze out in sheets instead of forming ridges along the edges of the pads.

Section 56

Improved Fabco pads with an improved coating on the bottom and a seal coat on top to keep them from sticking together in transit, were placed on 36 ties. For better retention of the coating on the bottom, the pad surface was abraded. The north 18 ties have ¼-in thick pads, exclusive of the coating, and the ⅛-in pads were placed in the south half of the section. Improvements to the pads are said to have been made by the use of better quality material and refinements in the manufacturing process. The new coating is softer than the 1951 formulation. After one train passed over some of the pads before spiking, the pads were stuck hard to the tie. In contrast, the J–M pads did not stick to the ties as well as the Fabco before spiking.

The purpose of this additional test is to compare two thicknesses of the improved Fabco pads and coating, and to secure more information as to the adequacy of the ⅛-in thickness. After 6½ weeks of service, when the initial or base readings for tie plate penetration, track gage, etc., were taken, there were no splits in the pads at the anchor spikes. At that time the coating appeared to have a tendency to form ridges along the pad edges rather than to squeeze out in sheets.

Special Anchor Spikes Retightened

In connection with the annual inspection of the tie plate fastenings made in June 1955, some maintenance work was performed on the special fastenings in 7 sections, as summarized in Table 3. The work performed, as well as the difficulties encountered, are described in detail in the notes below the table. This year all of the out-of-face work was the first general retightening for each of the sections since the inception of the test, except for section 10 (round-head cut spikes with single-coil washers, on tangent with pine ties) it was the second general retightening. Because the nuts were frozen on the dowel studs in section 11, the fastening could not be retightened by torqueing the nut on the studs without shearing off the stud in the oak ties or turning the fastening in the softwood ties. The studs do not have sufficient strength to remove them from the oak ties in order to unfreeze the nuts. The fastening, when in the tie, does not have sufficient bending strength to withstand the blows by a maul on a chisel for nicking and unfreezing the nuts. In the future the dowel studs requiring maintenance will be tapped down with a maul in hardwood ties and wrenched in the softwood ties. Some of the fastenings were reversed as to stagger in the plates. Some of the holes were plugged because one anchor spike only had lost its holding power. In the future the holes will be plugged wherever possible to delay using the last two anchor spike holes in the ties.

During the last 2-year period, all of the through bolts have been retightened out-of-face for the first time. About 10 percent of the low-reaction single-coil spring washers

TABLE 3. HOLD-DOWN FASTENINGS TAPPED DOWN OR RETIGHTENED ON THE L&N NEAR LONDON, KENTUCKY - JUNE 1955

			Long 4° -30' Curve		Tangent Creo. Oak Ties		Tangent Creo. Pine Ties		Total for each Construction	
Sec. No.	Hold-Down Fastenings	Date Built	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
10	2-Round Head cut spikes with single-coil spring washers	8-47	0	0	0	0	(a) 196	100	196	32
11	* 2-Round Head Dowel studs with double-coil helical spring washers	8-47	(b) 57	24	0	0	(c) 188	100	245	40
12	2-Oliver hold-down drive spikes with double-coil helical spring washers	8-47	(d) 8	3	0	0	0	0	8	1
14	* 2-Thru bolts with single-coil spring washers (field)	8-47	0	0	(e) 96	100	0	0	96	26
15	* 2-Thru bolts with single-coil spring washers (shop)	8-47	0	0	(f) 96	100	0	0	96	26
16	2-Screw spikes with double-coil spring washers	8-47	(g) 240	100	0	0	0	0	240	39
22	2-Oliver tie plate drive spikes with single-coil spring washers	8-47	-	-	0	0	(h) 58	31	58	15
Totals			305	23	192	17	442	39	939	26

Notes: Col. (1). Number of anchor spikes retightened or tapped down. Col. (2) Percentage of anchor spikes retightened or tapped down. All tie plates have a flat bottom and a 13-in length. (a) Stagger of anchor spikes was reversed in 4 plates due to loss of holding power. (b) One missing and 22 broken double-coil helical washers were replaced. Three dowel studs were sheared off in attempting to remove the fastenings for replacing the washers. In order to avoid breakage of the dowel studs, 29 were tapped down with a maul because the nuts were frozen. These fastenings lack the strength for removal from hardwood ties and also nicking the nut to unfreeze it, except after removing them from the ties. (c) All of the dowel studs in the softwood ties were retightened with a wrench. All of the fastenings turned in the wood except for three of the nuts which were not frozen. The average tightening was less than 1/8 of a turn. Stagger of the dowel studs where both were stripped in the same plate was reversed for 5 plates. Six studs stripped in the wood were replaced in the same holes by using plugs. Nineteen broken double-coil spring washers were replaced. (d) Only the 8 cone-necked fastenings without d.c. washers were tapped down. (e) Four missing and 10 broken single-coil washers were replaced. One bolt was twisted off after replacing the washer. This was caused by battered threads near the end of the bolt. (f) Four missing and 12 broken single-coil washers were replaced. One bolt was twisted off as described in item (e). In sections 14 and 15, no nuts were frozen and the torqueing averaged 1/2 turn of the nut. (g) Four screw spikes were stripped in the wood and 10 broken, d.c. washers were replaced. The screw spikes required from 1/4 to 1/2 turn to tighten. (h) Two missing single-coil washers were replaced. All of the broken d.c. washers were replaced with the Thackeray type. All of this work was done manually, requiring 20 man-hours. * All of the dowel studs in section 11 and the thru bolts in sections 14 and 15 were brushed with No-Ox-Id "A" Special in June 1955, requiring 9 man hours.

were broken or missing. This necessitated removing the nut and replacing the broken washers. This year, no trouble from frozen nuts was encountered in removing the nuts. Because of battered threads at the end of the bolts that had been struck, 2 bolts were sheared off in replacing the nuts. If it is possible to avoid broken washers on the through bolts, the maintenance work will be much less expensive.

This year, for the first time, all of the maintenance work performed on the special fastenings since installation has been summarized and is presented in Table 4. It is of interest to note that all of the 1947 types of construction have required some maintenance, except the tie plate lock spikes. The elastic spikes had the second lowest amount of repair, most of which was for the softwood tie section. Section 12 with the Oliver hold-down drive spikes was the third lowest. For the 1947 installations a greater percentage of the fastenings required maintenance in the softwood ties. For the installations made after 1947, the sections with Racor studs were driven home with an air hammer because it was not practical to do the work manually when they were originally installed. This was a matter of developing the proper method of driving the Racor studs and should be disregarded in appraising the various fastenings with respect to the cost of maintaining them. Because of the moderate plate cutting, it has not been necessary to tap down the cut spikes used as hold-down fastenings.

TABLE 4. SUMMARY OF SPECIAL HOLD-DOWN FASTENINGS TAPPED DOWN OR RETIGHTENED FROM THE DATE OF INSTALLATION THROUGH JUNE 1955 ON THE L&N RR., NEAR LONDON, KY.

Sec. No.	Hold-Down Fastenings	Date Built	*Long 4-1/2° Curve		Tangent Creo. Oak Ties		Tangent Creo. Pine Ties		Total for Each Construction	
			(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	1947 INSTALLATIONS									
10	2-Round Head cut spikes with single-coil spring washers	8-47	180	80	74	39	392	200	646	105
11	2-Round Head Dowel studs with double-coil helical spring washers	8-47	95	40	2	1	230	122	327	54
12	2-Oliver hold-down drive spikes with double-coil helical spring washers	8-47	46	20	6	3	134	70	186	30
22	2-Oliver tie plate drive spikes with single-coil spring washers	8-47	—	—	72	38	248	130	320	84
13	2-Elastic spikes, design No. 93	8-47	2	1	0	0	54	29	66	10
13	2-Tie plate lock spikes	8-47	0	0	—	—	—	—	0	0
14	2-Thru bolts with single-coil spring washers (field)	8-47	188	100	96	100	97	111	381	103
15	2-Thru bolts with single-coil spring washers (shop)	8-47	192	100	96	100	86	110	374	102
16	2-Screw spikes with double-coil spring washers	8-47	248	103	4	2	220	115	472	76
19	2-Screw spikes and double-coil spring washers with 13-in Erie RR. diamond bottom tie plates	8-47	254	108	—	—	—	—	254	108
17	2-AAR spring rail clips and screw spikes	8-47	258	116	228	133	236	137	722	128
1947 INSTALLATIONS - TOTALS			1463	73	578	39	1697	114	3738	75
	SUBSEQUENT INSTALLATIONS									
6	2-Racor studs (Built in Aug. 1947 with 2 Racor drive tight line spikes and changed to Racor studs Dec. 1949) (a)	12-49	—	—	128	100	128	100	256	100
43	2-Racor studs with 14-in tie plates on 5-deg test curve (a)	7-50	188	100	—	—	—	—	188	100
48	Racor coated tie pads and 2-Racor studs with 14-in tie plates	8-52	0	0	—	—	—	—	0	0
49	3-Racor studs, 14-in tie plates	8-52	0	0	—	—	—	—	0	0
49	4-Racor studs, 14-in tie plates	8-52	0	0	—	—	—	—	0	0
31	G&H Controls No-Creep rail anchors and 2-Oliver tie plate drive spikes without spring washers on anchored ties only, 14-in tie plates	8-49	—	—	96	100	—	—	96	100
34	2-Tie plate lock spikes, 14-in tie plates	9-49	—	—	0	0	—	—	0	0
SUBSEQUENT INSTALLATIONS - TOTALS			188	22	224	54	128	100	540	39
GRAND TOTALS			1651	58	802	42	1825	113	4278	67

Notes: Col. (1) Number of anchor spikes retightened or tapped down. Col. (2) Percentage of anchor spikes retightened or tapped down. All tie plates have a flat bottom and a 13-in length, except as indicated above. *Except as noted. (a) All Racor studs in sections 6 and 43 were tapped down with an air hammer in July 1951, because they were not driven home when originally applied with a maul. All maintenance work on the special hold-down fastenings, except the Racor studs, was performed manually. This work required 95 man-hours for retightening the special fastenings and 35 man-hours for applying No-Ox-Id "A" Special twice to the dowel studs in section 11 and the thru bolts in sections 14 and 15 to protect the exposed threads from corrosion. For more details of this work, see AREA Vol. 53, 1952, page 792; Vol. 54, 1953, page 1057; Vol. 55, 1954, page 728; Vol. 56, 1955, page 842 and Table 3 of this report.

Gage of Test Curves

A record of the gage of the two 4½-deg test curves is shown in Fig. 3. The figure includes the gage for each section at the time of installation and for the years 1954 and 1955. For the intervening years, see Vol. 56, page 843, Fig. 3. During the last year the gage in some of the cut spike sections of the long test curve has become more irregular, particularly in sections 1, 2, 9, 10 and 18. In the 1947 installations, sections 14, 15 and 17 had the best gage. In many of the sections the wide spots in the gage have increased during the last service period. Several of the special fastenings have continued to hold good gage, but there is evidence in some of the sections that this advantage has become smaller. In section 21 on the short 4½-deg test curve, the gage widened some. It was the intention to add some anchor spikes to this section, but only the south 24 tie plates in the outer rail had the spikes added in November 1953. This gage widening has been influenced by a cross swing and possibly by the Fabco pads. The best gage on the short curve is in section 26 with the Lackawanna diamond bottom plates, where only three spikes per plate were used.

Fig. 4 includes the record of the gage of the 5-deg test curve for the year of installation, and for the years 1954 and 1955.

Irregularity of the gage increased in several sections. In the 1950 installations, sections 37 to 43, incl., the gage had widened the most in sections 38 and 39, including the effect of replacing the pads. Section 43 with Racor studs, had the smallest gage widening.

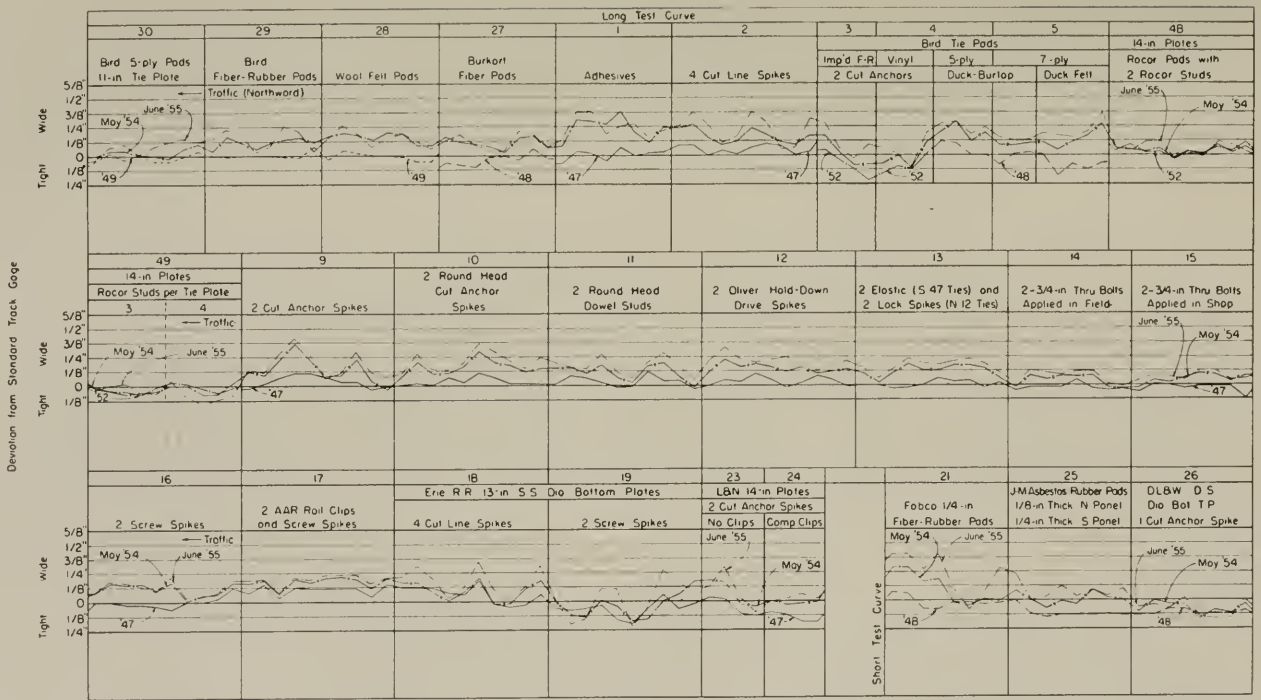
Fig. 5 gives the record of the gage of the 5-deg 36-min test curve where service tests are being made to determine the benefit of using compounds in the spike holes of the ties for holding track gage on a moderately sharp curve. Each of the test sections includes 3 panels of track. Section 01, used for controls represents the L&N standard construction. All spikes in section 02 were pulled and redriven after adding compound 8 in the tie holes, using the grooved plugs where needed. Rust Joint Iron with water was used in section 03. Compound 8 is a resin type wood hardener and is now being marketed in capsule form under the name of Tylife. Both of the compounds were effective in a laboratory test in restoring the holding power of cut spikes in enlarged holes.

After a service period of 34 months, the compounds have shown no particular advantage in controlling gage widening. Actually the average gage widening was the smallest in the control section. It is believed that because of the good tie condition in this curve, it may not be possible to develop the effectiveness of the two compounds, which are known to be beneficial in the case of spike-killed ties.

General Inspection

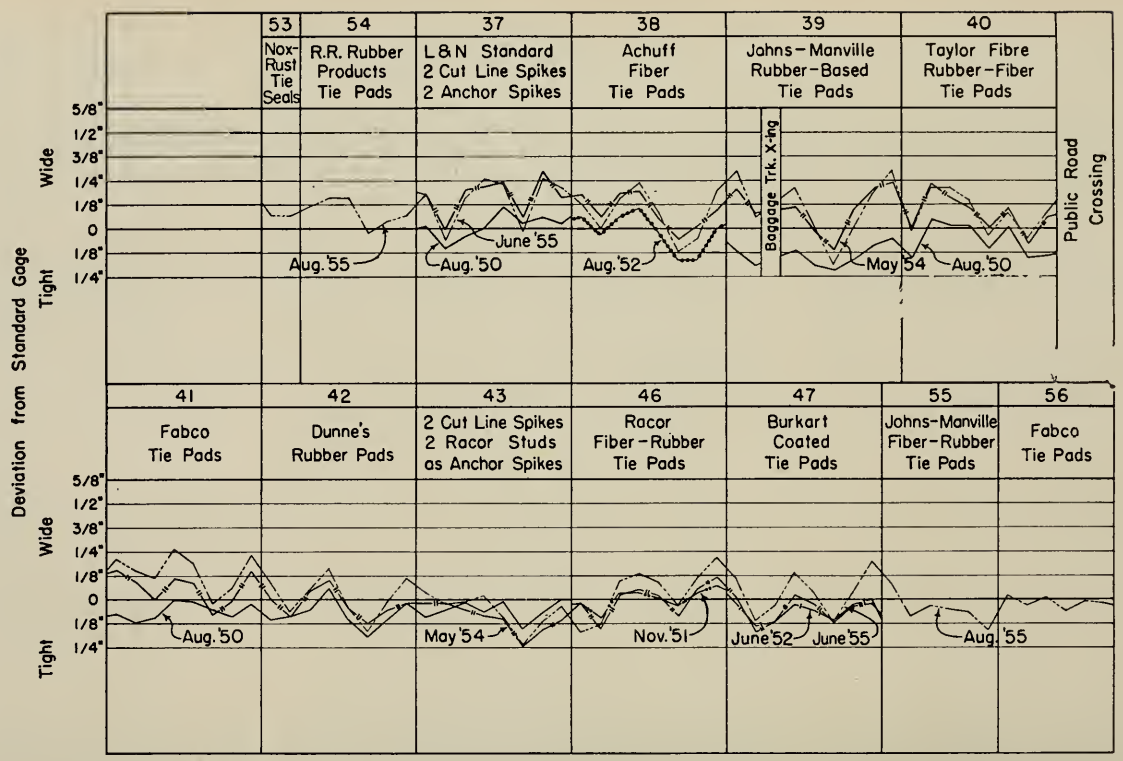
The annual inspection was made by the AAR research staff during the week of June 6, 1955, except that the examination of tie pads, coatings, etc., by the removal of the tie plates, was deferred for the subcommittee's visit on June 22. This year the attendance was the largest on record for this subcommittee, by virtue of extending an invitation to the members of the Tie committee and other members of the Association. Twenty-five members, including 5 associate members of the Association, were present. Eight of those members are on the Track committee, including four on this subcommittee. Ten of the members represented the Tie committee. In addition to 3 members of the research staff and 1 from the Timber Engineering Company, there were 18 other guests, representing 9 manufacturers. Four of the associate members represented 3 other manufacturers. The total attendance was 46 persons.

(Text continued on page 720)



Notes All test sections have 13-in tie plates, except as noted above All tie plates have a flat bottom, except as indicated otherwise Where no anchor spikes are indicated above, four cut line spikes per plate were provided Sections with anchor spikes have two cut line spikes The oldest gage record shown for each section represents the condition at the beginning of the original test or when a section was revised by changing the tie pads or fastenings The following sections were regaged Sections 4 and 5, Aug 1948, North portion Section 16 by relaying outer rail, Sept 1953, Section 21, Sept 1953, Two cut anchor spikes were added to the south 24 plates in the outer rail of Section 21, Nov 1953 All ties were installed as of the earliest date shown, except in Sections 3, 4 and 5, the 1947 ties were retained in service

Fig 3 Gage, Curvature and Elevation of Each Section of Test Track on the 4°-30' Curves, Mile L-154, L&N R R, near London, Ky



All sections have new AREA 14-in Plan 12 flat bottom tie plates, except sections 46 and 47, which have second hand AREA Plan 68 flat bottom tie plates. All sections have two each of cut spikes for line and anchor, except as noted.

----- After replacing pads in 1952

Fig. 4. Gage, Curvature and Elevation of Each Section of Test Track on the 5-deg Curve, Mile L-153, L.&N.R.R., at East Bernstadt, Ky.

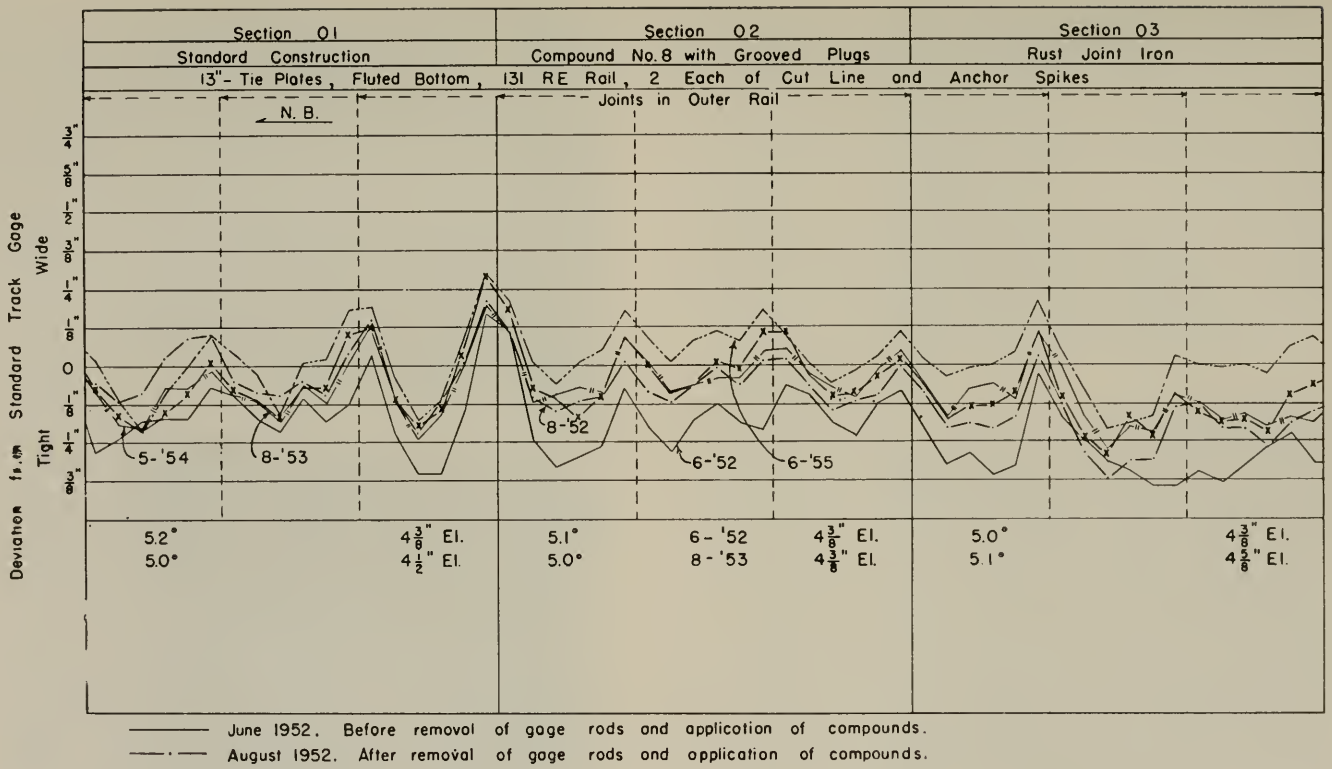


Fig. 5 Gage, Curvature and Elevation of Sections 01, 02, and 03 in 5°-36' Curve, Mile L-152, L. & N. R.R.

During the subcommittee's inspection, 18 tie plates were removed to examine tie pads, underplate coatings and the adzed surfaces of the ties. Photographs showing the conditions observed are presented in Figs. 6 to 23, incl. Below the title of each figure, comments on the conditions observed are listed. For each construction the specimen selected for examination represented the average condition. Some compression of the ties was found under the tie pads on all three test curves. It will be observed in the figures that the pads in Figs. 14, 16 and 17 had the best bond with the ties. By comparing Figs. 22 and 23, it can be seen that the application of Anker-Seal filled the tie plate holes much better than the Protek-Tie in Fig. 22. Most of the compounds had been squeezed out from under the tie plates.

Each year all of the test sections are inspected in detail, and the deficiencies are noted. Some of the tie pad sections are now developing some major damage, such as serious dislocation and delamination, stretching, mashing out, becoming torn and ripping at the spikes. These observations will become more significant in the future and will be reported at that time.

Based on the service tests for different periods (as shown in years in parentheses following each pad designation), the following tie pads have shown the better performances: Bird original fiber-rubber (6); Bird improved fiber-rubber (3); Fabco (8, 7, 5 and 4); Bird 5-and 7-ply duck-burlap (7 and 6); Burkart fiber (7 and 3); Dunne's molded rubber (5); Racor fiber-rubber (3.7 and 3); and Bird vinyl pads (3). The following types of tie pads were superior as to retaining a good seal with the ties: Bird 5- and 7-ply tie pads (8, 7 and 6 years); and Bird vinyl tie pads (3 years).

(Text continued on page 729)

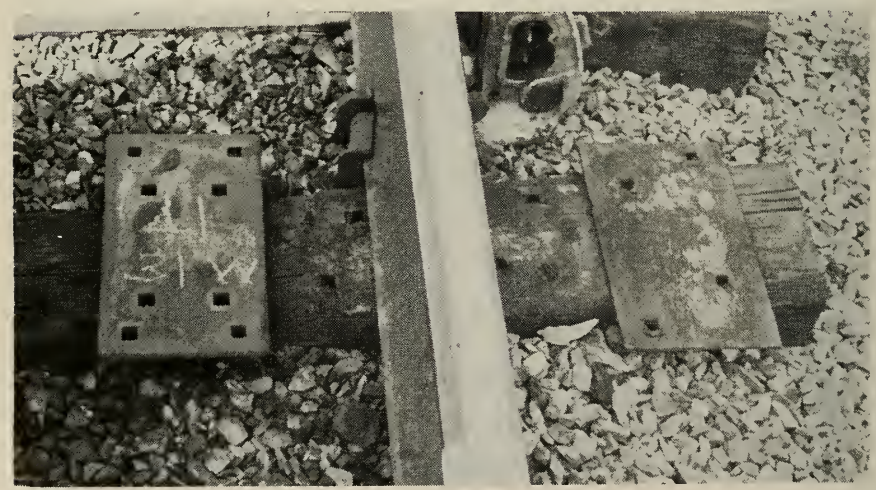


Fig. 6—Middle portion of section 41, 14-in (1951) Fabco tie pad, bottom coated, 47 months of service, inner rail, 5-deg curve. Some sand. No bond with tie. Two-thirds of coating left on wood. Pad condition good.

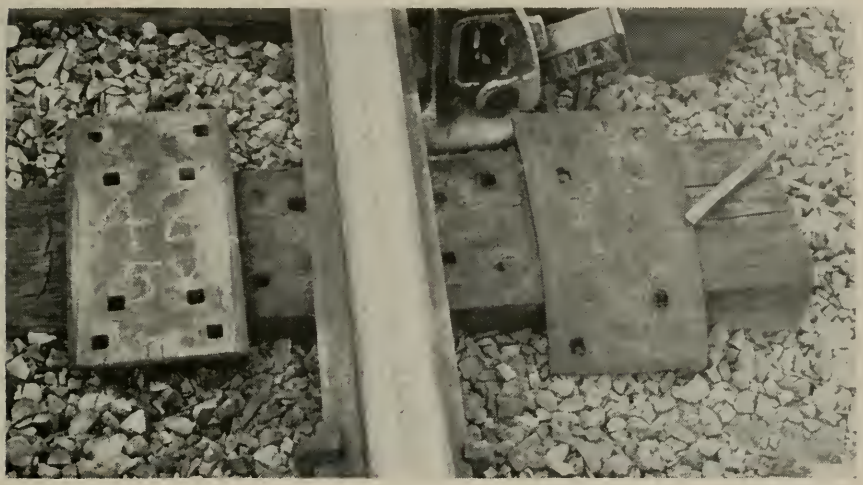


Fig. 7—Section 42, Dunne Rubber Company 14-in molded rubber tie pad, ⅛ in thick, uncoated, 59 months of service, inner rail, 5-deg curve. Sand had pitted pad on both sides. Pad had a short transverse split at the vacant line spike hole on the gage end and slight compression at the field end. Minor compression and abrasion of the tie by the sand imbedded in the ridges of the pad. Little wood compression at field end.

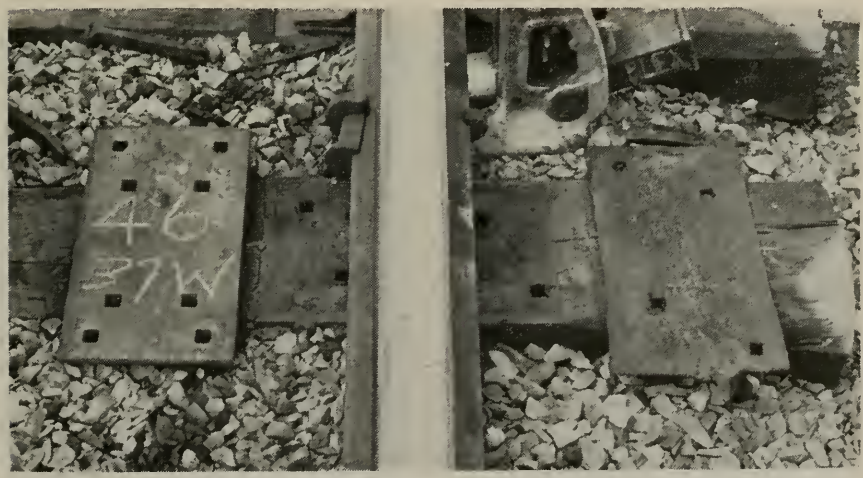


Fig. 8—South portion of section 46, 14-in Racor tie pad, coated, 43 months of service, inner rail, 5-deg curve. Little sand at gage end, other area under pad was clean. Little bond. Coating was left on seven-eighths of the tie area under the pad. No abrasion of tie. Pad was damaged moderately by a knot in the tie at the field end.

Fig. 9—Section 47, 14-in Burkart tie pad, bottom coated, 3 years of service, inner rail, 5-deg curve. Pad was not sealed down, but the under-pad area was clean except for some sand at the gage end. Practically all of the coating on the pad and tie was gone. Pad was in good condition except that a longitudinal sliver had been squeezed into the split in the tie.

Fig. 10—Section 30, 11-in Bird 5-ply duck-burlap tie pad, coated, 69 months of service, inner rail, north spiral of long 4½-deg curve. Pad had a seal sufficient to keep the under-pad area clean and was in good condition. Slight compression of the wood at the field end.

Fig. 11—Section 29, 13-in Bird original fiber-rubber tie pad, serrated surfaces, coated, 69 months of service, inner rail, north spiral of long 4½-deg curve. Pad had a weak bond. Some sand on tie and pad. About one-fourth of the under-pad area was covered with the coating. Pad condition was good.

Fig. 12—Section 27, 13-in Burkart fiber pad, uncoated, 80 months of service, inner rail, long 4½-deg curve. Pad was in reasonably good condition and had stretched lengthwise ½ in. Under-pad area was clean except for sand at gage end. Slight compression of wood at field end.

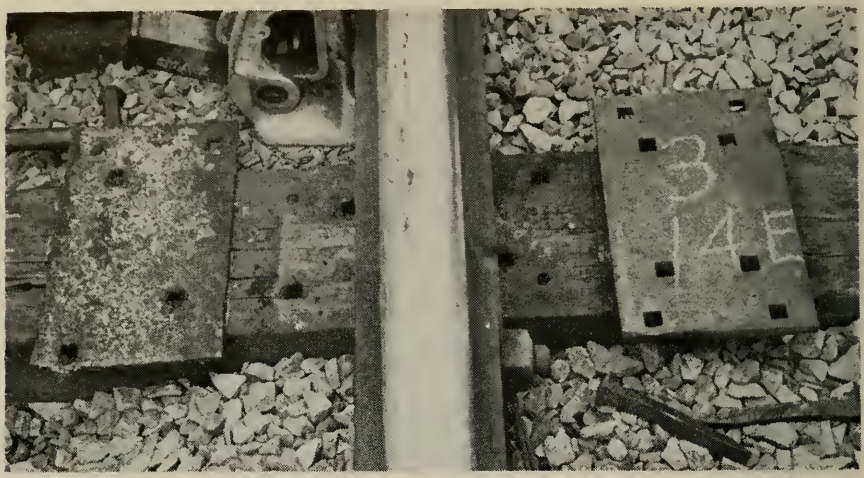


Fig. 13—Section 3, 13-in Bird improved fiber-rubber pad, abraded surface, coated, 3 years of service, inner rail, long 4½-deg curve. Pad was not sealed to tie. Most of the coating adhered to the bottom of the pad with little left on the wood. Some sand on the tie and bottom of the pad. Pad was in good condition except for slight compression at the field end and minor damage at the field anchor spike.

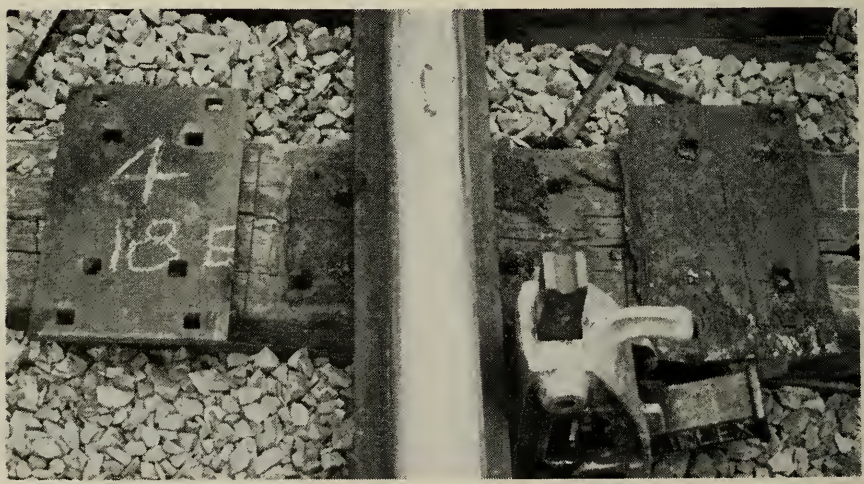


Fig. 14—North portion section 4, 13-in Bird vinyl tie pad, coated, 3 years of service, inner rail, long 4½-deg curve. Good strong bond. Clean surface under pad. Pad condition good. Most of the coating adhered to the pad. Compare with section 47, Fig. 9.

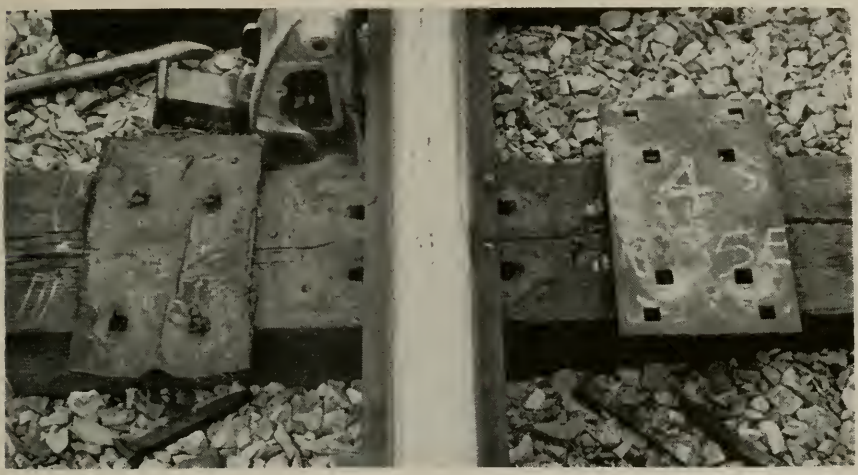


Fig. 15—South portion section 4, 13-in Bird 5-ply duck-burlap tie pad, coated, 82 months of service, inner rail, long 4½-deg curve. Pad seal was weak. Under-pad area was clean except for some sand at field end. Little compression of wood at field end. Pad was damaged some by delamination but had prevented tie abrasion.

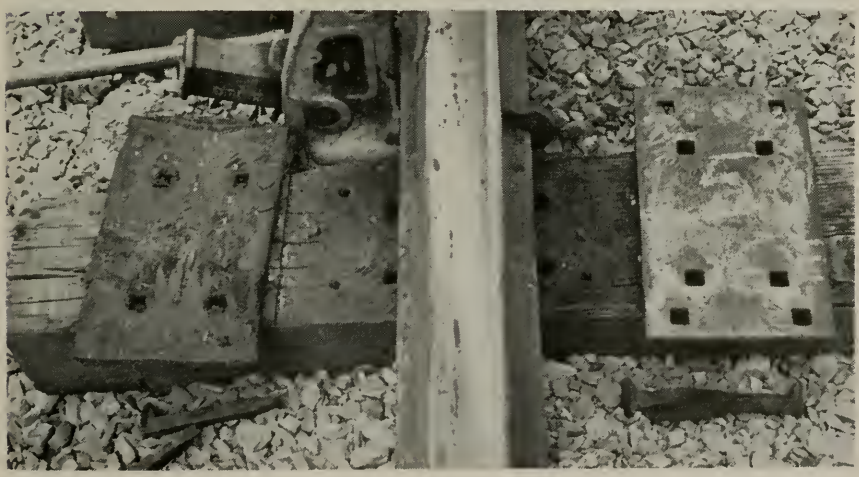


Fig. 16—North portion section 5, 13-in Bird 7-ply duck-burlap tie pad, coated, 82 months of service, inner rail, long 4½-deg curve. Strong seal under rail base. Two top plies of pad were worn. Some sand. Slight compression of wood at field end.

Fig. 17—South portion section 5, 13-in Bird 7-ply duck-felt tie pad, coated, 94 months of service, inner rail, long 4½-deg curve. Strong bond. Clean surface under pad. Little compression of wood at field end. Pad was damaged by some delamination, and the bottom ply was torn.

Fig. 18—Section 48, 14-in Racor pad, coated, 2 Racor studs, 34 months of service, inner rail, long 4½-deg curve. Weak bond. Clean surface under pad. Coating left on two-thirds of the area under the pad. No compression or abrasion of the tie. Pad condition good.

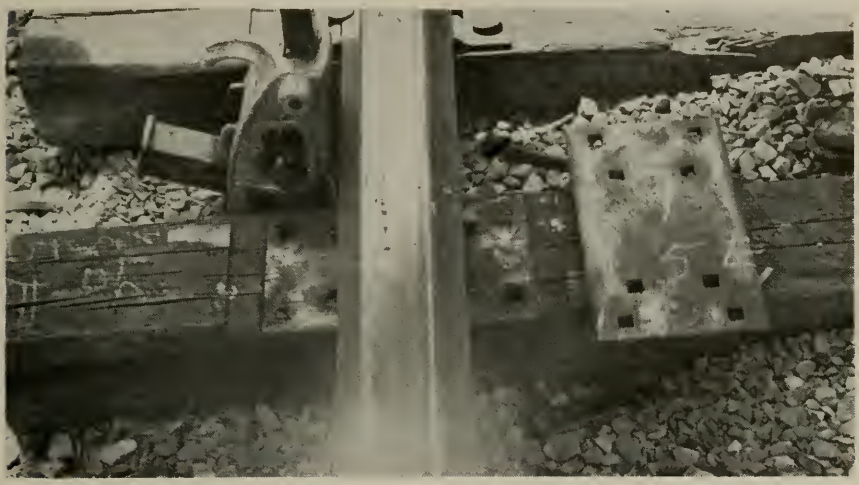


Fig. 19—Section 9, 13-in tie plate with 2 each of cut line and anchor spikes (control section), 94 months of service, inner rail, long 4½-deg curve. Little sand under tie plate. Average plate cutting was approximately 0.08 in.

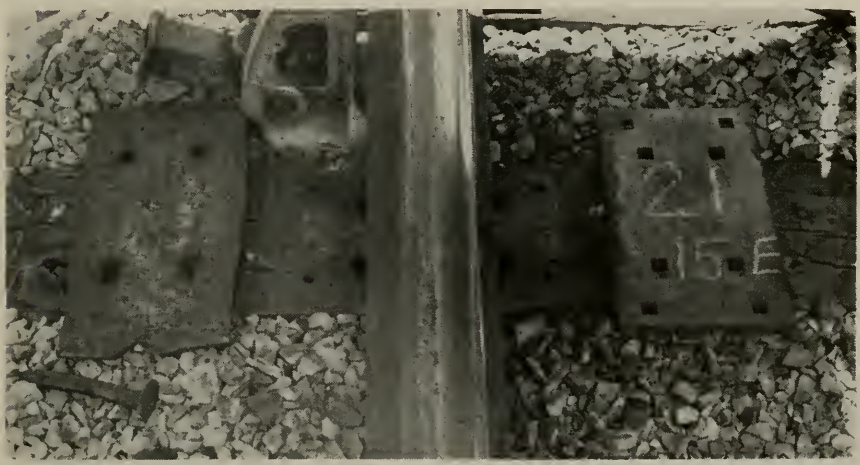


Fig. 20—Section 21, 13-in Fabco tie pad, uncoated, 82 months of service, outer rail, short 4½-deg curve. About one-half of the area of the tie under the pad was damp; no free water was found under other pads or plates. Considerable rain had fallen in the area two weeks before the inspection. Sand was found on the pad and tie except at the gage end of the plate. The pad was damaged some under the rail base and had stretched to an average of 1¼ in. in excess of its original length. Slight compression of the wood at the field end.

Fig. 21—North portion section 25, 13-in J–M laminated asbestos-rubber tie pad, 1/8 in thick, uncoated, 82 months of service, outer rail, short 4½-deg curve. No bond. Some sand and a little moisture on the under-pad area. This type of pad abraded the tie a little during the early part of the service period because the pad was too hard. It has retained its dimensions and was in excellent condition.

Fig. 22—Section 52, paddle coat of Protek-Tie applied to adzed surfaces of creosoted oak tie, 22 months of service, tangent track. Upper view—Before removing tie plate. Lower view—After removing tie plate. Note that the vacant tie plate holes were not filled with the smear. There was some sand and some tie abrasion.

Fig. 23—Section 50, paddle coat of "Anker Seel" applied to adzed surfaces of creosoted oak tie, 23 months of service, tangent track. Upper view—Before removing tie plate. Lower view—After removing tie plate. Note that the vacant tie plate holes were well filled. There was a little sand and abrasion under the plate. From a general inspection this smear had sealed the edges of the plate better than the Protek-Tie in section 52.

Tie Coating

Koppers No. 16 sealing compound was applied to the top and ends of new and existing creosoted hardwood ties in July 1950 to investigate its capacity for retarding the splitting, checking and weathering of the timber. Section 35 included 120 new ties, and the coating was applied to all of the adzed surfaces, before placing the ties, and on the top of the odd numbered ties, leaving the other ties for controls. In addition, the compound was also brushed on the ends of the coated ties in the south half of the section. Section 36, consisting of 118 existing ties, had all ties coated on top and also the ends of the south 58 ties. The tops of all ties coated were sprinkled with ¼-in washed gravel for a protective covering. The test sections are located in fast tangent track laid with 131lb rail, 6-hole joints, and 13-in tie plates with waffle bottoms. W. J. Finnorn, wood technologist, Timber Engineering Company, with the assistance of a member of the AAR research staff, made the fifth annual inspection, June 21, 1955. During the month previous to the inspection the temperature and rainfall were about normal. Heavy rains occurred two weeks before the inspection.

The efficiency index of the coating for keeping the splits covered was determined from the number of splits ⅛ in wide or larger on the top end faces of the ties. The efficiency factors for the new ties in section 35 were obtained from the following formula:

$$\text{Efficiency, percent} = 100 - \left(\frac{\text{Number of checks in coated ties}}{\text{Number of checks in uncoated ties}}\right) \times 100$$

Because all of the existing ties were coated in section 36, the original number of splits in the ties before being coated was used for computing the efficiency factors.

Values of the coverage efficiency of the coating for the 5-year test are tabulated below:

Category	Section 35 1950 Ties Percent					Section 36 Existing Ties Percent				
	1951	1952	1953	1954	1955	1951	1952	1953	1954	1955
All coated ties	75	74	76	52	52	82	82	70	48	55
Ties coated on top only	70	63	73	48	45	64	75	61	36	44
Ties coated on top and ends	79	85	80	55	60	97	89	79	60	66

In 1954, for the first time, there was a sharp drop in the efficiency factors for all categories. This year, with more favorable weather in the preceding two weeks, four of the factors increased moderately. For the ties coated on top only, which represents the normal application of sealing compounds, the factor dropped from 48 to 45 percent for the 1950 ties, and increased from 36 to 44 percent for the existing ties. Figs. 24 and 25 show the condition of the ties and coatings in the two test sections. The coating has continued to weather away more on the existing ties than on the 1950 ties. Some of this deficiency was caused by plowing ballast out of the track. The coating had become thin in places, but did not peel off the ties. It did not appear that the bare areas on the tops of the ties had increased much during the last year. In the bottom view of Fig. 24, the uncoated tie in the middle had a large splinter broken off. A check of the ties in section 35 indicated that a total of 7 ties had a large splinter broken off, similar to the tie shown in Fig. 24. Five of the ties were uncoated and 2 were coated on top, including 1 with the ends coated. It is not believed that the coating was a factor in this splintering.

At the last inspection, the number of checks 1/8 in and wider not covered by the coating in the 1950 coated ties was 58, compared to a total of 122 for the uncoated ties. For every check uncovered in the coated ties there were 2 checks in the uncoated ties.

Measurements of the moisture content of the top 3/8-in of ties were made with a Delmhorst moisture detector to determine the efficiency of the coating for retaining moisture in the top portion of the ties. To compare the coated existing ties with those not coated, moisture readings were taken in the existing ties south of section 36. These data are summarized in the table below in percent of the weight of oven dry wood.

Date	Section 35 1950 Ties			Section 36 Existing Ties		
	Coated	Uncoated	Difference	Coated	Uncoated	Difference
July 1951	16.5	10.2	6.3			
June 1952	20.6	10.9	9.7	29.8	12.3	17.5
July 1953	18.5	11.8	6.7	24.7	11.5	13.2
July 1954	11.9	9.3	2.6	12.2	8.8	3.4
June 1955	13.1	11.5	1.6	14.0	11.6	2.4

Although the average moisture content for both the coated and uncoated ties was higher this year than for last year, the excess moisture of the coated ties over that of the uncoated ties was reduced further. During the fifth year of service, the coating has continued to lose its effectiveness for retaining moisture in the upper part of the ties. Most of the surface coating is still in place, but it has oxidized and deteriorated to such an extent that its effective life for the retention of moisture appears to be expended. However, the efficiency of the coating for keeping a cover over the checks is 45 and 44 percent for the ties coated on top only in sections 35 and 36, respectively. It is desired to continue this test for another year or two to develop more information.

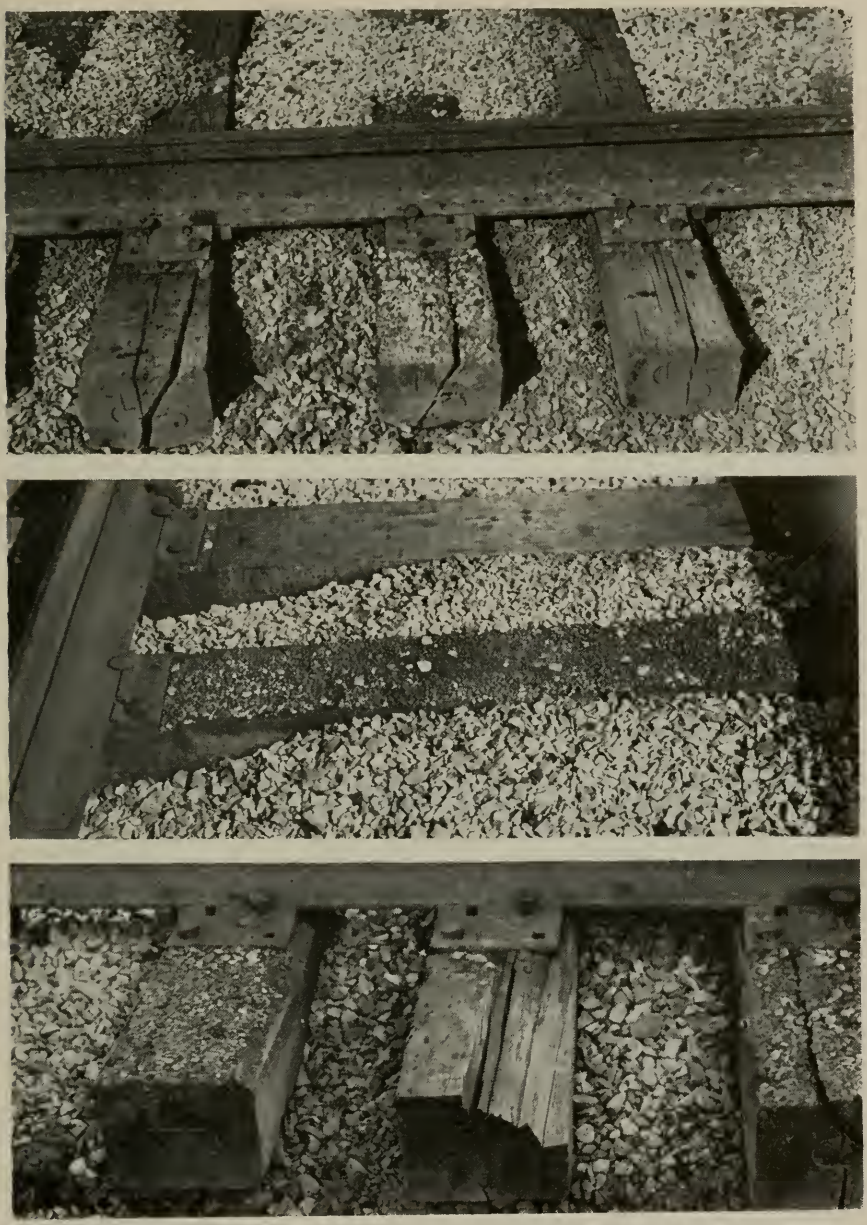


Fig. 24—Section 35, Koppers' No. 16 sealing compound on alternate new creosoted oak ties, 59 months of service, tangent track. Top view—The middle tie was coated on top only and was one of the poorer coated ties. Middle view—Typical condition of coating between the rails. Bottom view—End view of uncoated tie No. 6 showing shattering or splintering effect which had occurred on several ties.

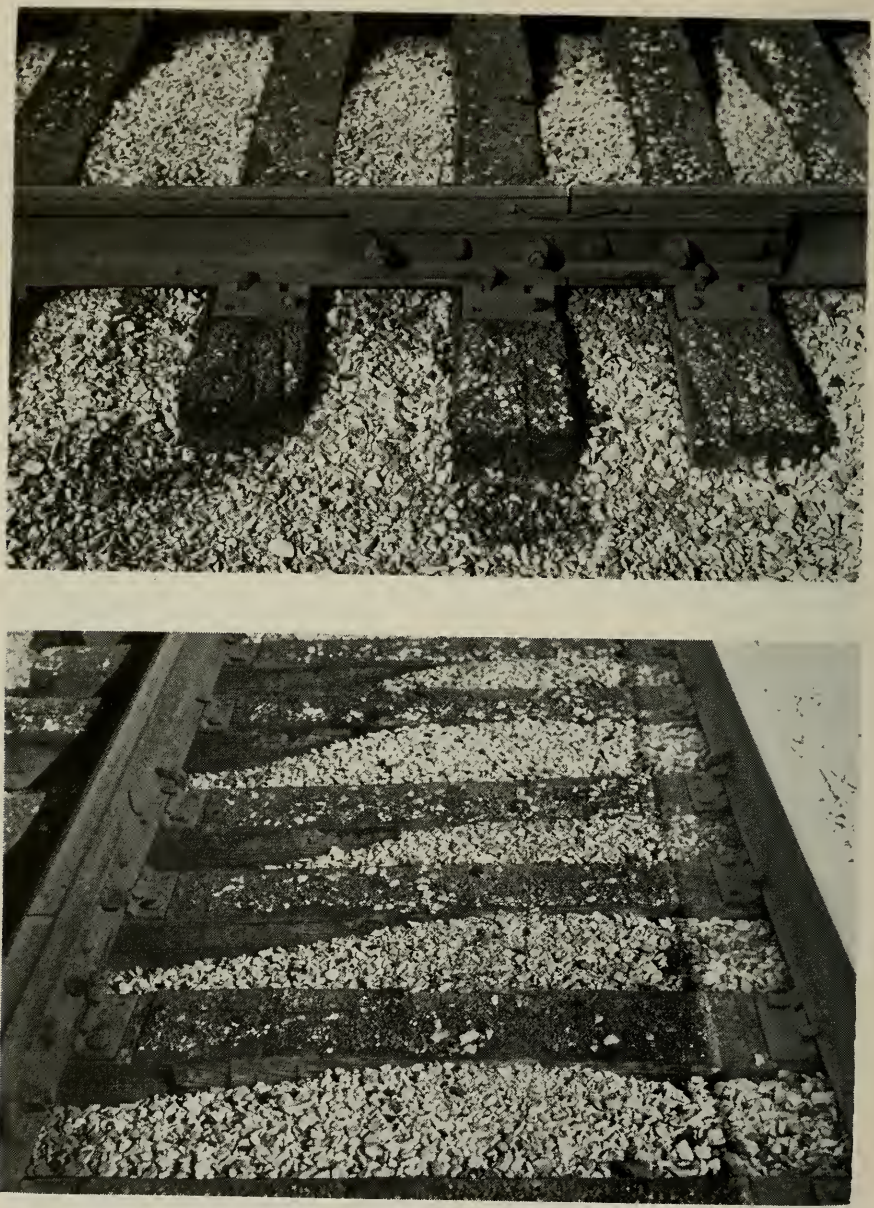


Fig. 25—Section 36, Koppers' No. 16 sealing compound on existing hardwood ties, 59 months of service, tangent track. Upper view—All ties were coated on top and only the right one was coated on the ends. The left tie had one check over 1/8 in wide and the other 2 ties had none. Lower view—Typical view of the coating on the ties between the rails. Note the areas where the coating had disappeared. This was caused by weathering and partly by plowing out new ballast used in dressing the track.

Summary and Conclusions

In general, most of the tie pads, coated or uncoated, have practically eliminated tie abrasion. Some compression of the hardwood ties on the test curve and of the softwood ties on tangent has occurred under the pads. The coated pads with a long lasting seal have protected the underplate areas better than uncoated pads, particularly in reference to damage of the wood fibers, by virtue of keeping the sand and water out from under the pads. With uncoated pads on the softwood ties, the inspections have shown that sand had accumulated under them and had abraded and pitted the softwood ties more than the hardwood ties. It is tentatively concluded from this information that pads with good sealing qualities should benefit the softwood ties more than the hardwood ties, particularly where engine sand or wayside abrasives are present to an appreciable extent.

The fiber-rubber type of tie pad had not retained a seal with the adzed surfaces as long as the laminated fabric type and one make of fiber pad. Some of the older pads in the acceptable group are showing major damage. However, inspections have shown no appreciable tie abrasion under damaged pads where the tie plates were not in contact with the wood.

In this report, a resumé of the maintenance work required for the special tie plate fastenings has been given. During the 8-year service period, the tie plate lock spikes have required no maintenance. The Racor studs have had no cyclic maintenance. Because they could not be driven properly by hand, it was necessary to drive them down to the proper level with an air hammer. The Elastic spikes have required a little work, principally in the softwood ties. The maintenance has also been little with the Oliver hold-down drive spikes in the hardwood ties. The foregoing fastenings have reduced plate cutting 42 to 66 percent as compared with cut spike construction. The Koppers No. 16 sealing compound has lost most of its effectiveness for the retention of moisture in the upper part of the hardwood ties, but its efficiency for keeping the checks covered is still about 45 percent.

Acknowledgment

The Association is indebted to the Louisville & Nashville Railroad and to the manufacturers involved, for the assistance rendered in the conduct of these service tests.

TESTS ON THE ILLINOIS CENTRAL

Foreword

Since 1944 the AAR research staff has taken tie plate penetration measurements periodically in the middle main track of the Illinois Central where the railroad had installed in 1943 a test of hold-down fastenings in 3 miles of track laid with new ties and 131 RE rail, north of Manteno, Ill. This test includes 1 miles each of creosoted pine, gum and oak ties. Each mile is divided equally with two different lengths of tie plates, and each ½ mile includes 7 arrangements of hold-down fastenings. The middle main traffic consists largely of passenger trains and the higher-speed freight trains operating in both directions. The last report on this service test was published in the Proceedings, Vol. 55, 1954, page 747.

Tie Abrasion

Measurements of tie abrasion for 19 rails in the 3 miles of track were made in April 1955. Table 5 gives a summary of these data and data on loose plates and double-coil spring washers. The traffic during the 10½-year test period amounted to 149 million gross tons, or an increase of 25 million since the observations made in April 1953.

TABLE 5 - SERVICE TEST OF MECHANICAL WEAR OF TIES WITH TWO DESIGNS OF TIE PLATES AND THREE KINDS OF TIES IN THE WEST RAIL OF THE MIDDLE TRACK OF THE ILLINOIS CENTRAL SYSTEM, BETWEEN M. P. C-42 AND M. P. C-45, NORTH OF MANTENO, ILLINOIS

Tangent Track - Traffic in both directions. New 131-lb. RE rail with 6-hole joints laid in 1943. All ties 7 in. by 9 in. by 8 ft. 6 in. renewed in 1943.

Mile	Kind of Cross Ties	Number and Kind of Anchor Spikes per Tie Plate	Tie Plate Penetration in 0.001 in. October 1944 to April 1955 (149 Million Gross Tons)			Relative Wear in Percent	Percent Loose Plates	Percent Loose Washers
			End of Tie Plates					
			Field	Gage	Avg.			
7 3/4 in. by 13 in. by 27/32 in. double shoulder tie plates, rolled circular crown, 1:40 ± cant, flat bottom, level shoulder extensions, eccentricity 1/4 in., AREA Plan No. 5B.								
C-43	Creo. Pine	None	203	216	210	100	68	
C-43	Creo. Pine	4 S. S. *	170	217	194	92	23	
C-43	Creo. Pine	2 S. S.	159	180	170	81	48	
C-43	Creo. Pine	4 S. S. with double coil washers	183	194	188	90	10	25
C-43	Creo. Pine	2 S. S. with double coil washers	151	171	161	77	32	39
C-43	Creo. Pine	4 Cut Spikes	170	223	196	93	59	
C-43	Creo. Pine	2 Cut Spikes	175	189	182	87	64	
C-44	Creo. Gum	None	110	137	124	100	80	
C-44	Creo. Gum	2 S. S. with double coil washers	60	85	72	58	14	5
C-45	Creo. Oak	None	98	117	108	100	55	
C-45	Creo. Oak	2 S. S. with double coil washers	68	64	66	61	5	2
C-45	Creo. Oak	2 Cut Spikes	128	124	126	117	82	
7 1/2 in. by 14 3/4 in. by 31/32 in. double shoulder tie plates, rolled circular crown, 1:40 ± cant, wave bottom, tapered shoulder extensions, eccentricity 1/2 in., Penna. R.R. Standard								
C-43	Creo. Pine	None	170	204	187	100	82	
C-43	Creo. Pine	2 S. S. with double coil washers	109	108	108	58	20	12
C-44	Creo. Gum	None	150	159	154	100	77	
C-44	Creo. Gum	2 S. S. with double coil washers	108	107	108	70	0	11
C-45	Creo. Oak	None	100	126	113	100	77	
C-45	Creo. Oak	2 S. S. with double coil washers	87	74	80	71	0	2
C-45	Creo. Oak	2 Cut Spikes	134	136	135	119	86	

*S. S. = Screw Spike. All tie plates have 15/16" dia. anchor spike holes.

The screw spike sections with 13-in tie plates and softwood ties have continued to be less effective in reducing plate cutting during the last 2 years. During that period the cut spike sections showed no acceleration in the rate of tie wear, but the data for the screw spike sections indicated an appreciable increase with respect to the traffic. Two years ago the screw spike sections had reduced the plate cutting 17 percent below that for the cut spike construction. The corresponding figure for April 1955 had dropped to 9 percent. The plate cutting for screw spikes with and without double-coil washers was about the same. Earlier in the test the double-coil washers indicated greater effectiveness for reducing tie abrasion. It will be observed from Table 5 that the plate cutting of 4 screw spikes vs 2 screw spikes, with or without washers, was greater with 4 screw spikes.

For the test conditions it can be concluded that the economy of using 4 screw spikes for minimizing plate cutting is at least questionable. It is possible that a general retightening of the screw spikes in the 13-in tie plates on the softwood ties will restore their efficiency unless many of the screw spikes are stripped in the ties. The screw spikes in all of the other test sections have continued to be moderately effective in minimizing plate cutting, with reductions ranging from 30 to 42 percent of the respective control sections with cut spikes. Other service tests have indicated that screw spikes with double-coil washers have effected a 50 percent reduction in plate cutting, compared with cut spike construction.

Because the 14¾-in tie plates have wave bottoms (which promote rapid early plate settlement), and the 13-in plates flat bottoms, the effectiveness of the larger plates in reducing plate cutting in corresponding test sections was not developed. Considering all of the cut spike sections in each category and using the softwood ties as a base for comparison, the 13-in plates showed 37 and 45 percent less plate cutting for the gum and oak ties, respectively. The corresponding figures for the 14¾-in plates were 18 and 34 percent, respectively. The gum ties were plate cut 15 percent more than the oak ties with the 13-in plates, compared with 24 percent for the 14¾-in plates, thus giving an average figure of 20 percent. Because of the short test sections used, the 20 percent figure may not be exactly in accordance with the findings by the Member Roads that use creosoted gum ties.

In addition to retightening the screw spikes out-of-face on the softwood ties with 13-in plates, it is indicated by the data on loose plates and washers that spot retightening should be done in the other test sections. No work has been done on the screw spikes since the last report.

Acknowledgement

The Association is indebted to the Illinois Central for the assistance rendered in the conduct of this service test, and extends its appreciation to the suppliers for furnishing their materials for the test.

Report on Assignment 7

Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings

R. G. Garland (chairman, subcommittee), L. L. Adams, John Ayer, Jr., E. G. Brisbin, T. F. Burris, W. E. Cornell, H. W. Cox, Jr., W. E. Griffiths, C. J. McConaughy, J. M. Rankin, M. K. Ruppert, G. R. Sproles, R. E. Tew.

This progress report consists of two parts: (1) the results of a 5-year service test of rail joint preservation on the Illinois Central Railroad, and (2) the results of a laboratory brine corrosion test with 11 metal preservatives, and is submitted as information.

This investigation was conducted by the AAR research staff under the general direction of G. M. Magee, director of engineering research. H. E. Durham, research engineer track, was in direct charge of the field tests and was assisted by A. D. Van Sant, assistant research engineer track, and other members of his staff. S. K. Coburn, chemical engineer, was in direct charge of the laboratory tests.

Part 1

SERVICE TESTS ON THE ILLINOIS CENTRAL

Introduction

This test, consisting of 10 original sections, was begun in June 1950 in connection with the laying of 132 RE rail with 6-hole headfree joint bars in the northward main of the Illinois Central, south of Chebanse and Ashkum, Ill. The two stretches of test track are on tangent with light grades and fast traffic, about 15 percent being reversed movements. All of the passenger traffic and a portion of the freight tonnage are hauled by diesel power. Heavy steam locomotives of the 4–8–2 type operate in freight service. During the fifth service period of 11½ months, ended July 7, 1955, the test track had carried 26.1 million gross tons of traffic. The total traffic for the test period, from August 1950 when the initial measurements were taken, was 153.0 million gross tons.

In 1953, protection of rail joints by spraying metal preservatives behind the joint bars was started in original test sections 3 and 10, where the previously applied compounds had failed. The three test sections sprayed first in 1953 will be discussed later. This year the spray method of joint preservation was expanded by starting a test with three spray materials in Miles 75 and 76 of the southward main, laid in 1944 with 131 RE rail with 6-hole headfree joint bars. Fig. 1 shows the location of the original test section in detail, and the general location of the test started in the southward main, which is adjacent to the original test sections south of Ashkum. This year, since most of the 5-year old sections had brush coat protection only, some of the installations will be terminated so that a concerted effort can be made in the investigation to determine the economical and effective methods for preserving old rail joints, which is the major problem.

Discussion of Test Data

Rail Joint Gap

Each winter and summer the rail gap widths are measured for the yearly range in rail temperature to determine the pattern of rail gap widths and whether there was any difference in the uniformity of rail gap in the test sections. These data have been summarized for the last winter and summer in Figs. 2 and 3, consisting of bar diagrams for each 0.05-in increment of rail gap width. The measurements of January 1955, with an average rail temperature of 21 deg F, showed for the original 10 test sections fewer joints in the first 2 increments than in the previous winter when the rail temperature averaged 35 deg F. Although there was a difference in the rail temperature for the last 2 winters, it can be concluded that there was no tendency for an increase in the number of frozen joints. Sections 1, 6 and 10 had the largest percentage of joints in the first 2 increments of rail gap width, but none was in excess of 15 percent. Section 7 had, by a small margin, the best uniformity of winter rail gap by virtue of having the greatest percentage of joints in the 3 increments centered about the one that included the average joint gap of 0.28 in for that test section. The July 1955 measurements (Fig. 3) were taken at an average rail temperature of 120 deg F, the highest for the 5-year test period. For the original 10 test sections, there was a greater percentage of joints in the first increment than in any of the previous summers. The lowest percentage of joints in the first increment occurred in August 1950, the first summer, and was about one-half as many joints as in July 1955. In 1950 the average rail temperature was only 108 deg F.

(Text continued on page 740)

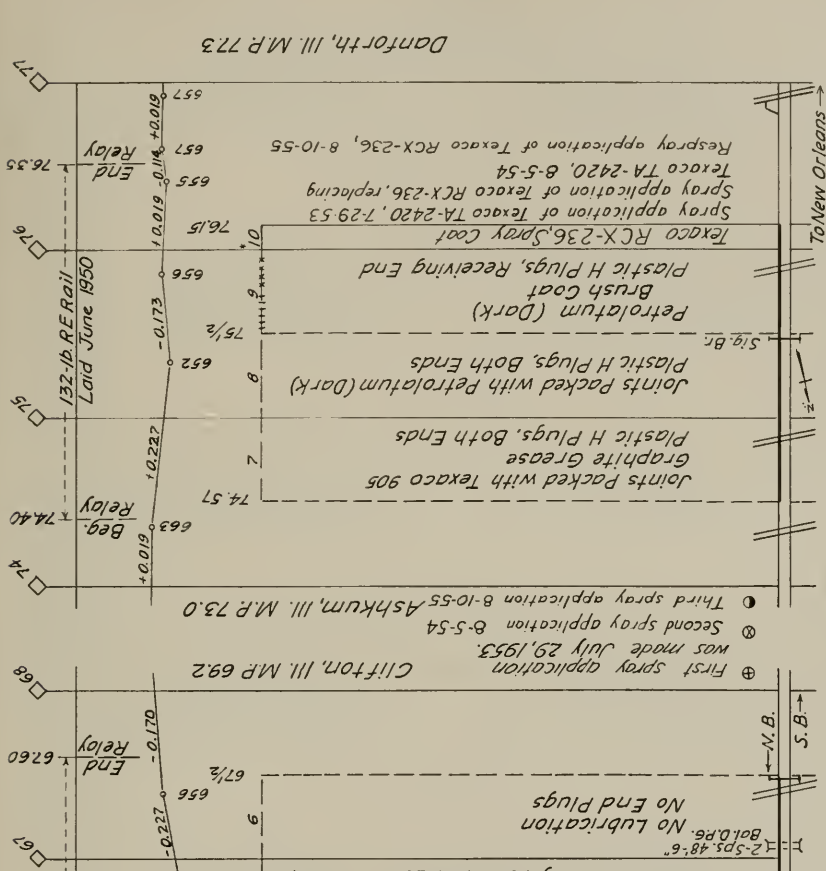

Danforth, Ill. M.P. 77.3
Cheb anse, Ill.
Clifton, Ill. MP 69.2
Ashkum, Ill. M.P. 73.0
To New Orleans
To Chicago
Depot
N.B.
S.B.
132-lb. RE Rail
Laid June 1950
36 in. 6-hole
132-lb. RE Rail
H.F. Joint Bars
Beg. Relay
End Relay
Sig. Br.
Open Deck
Joints Packed with Texaco 905
Graphite Grease
Plastic H Plugs, Both Ends
Joints Packed with Petrolatum (Dark)
Plastic H Plugs, Both Ends
Petrolatum (Dark)
Brush Coat
Plastic H Plugs, Receiving End
Texaco RCX-236, Spray Coat
Spray application of Texaco TA-2420, 7-29-53
Spray application of Texaco RCX-236, replacing
Texaco TA-2420, 8-5-54
Respray application of Texaco RCX-236, 8-10-55
Conoco Anti-Rust Compound
Brush Coat
Plastic H Plugs, Both Ends Middle 21 Jts.
Texaco No. 941 Spray Coat, West Roll
Barcote No. 600, Spray Coat,
East Roll
No-Ox-Id "A" Special
Brush Coat
No-Ox-Id Plugs, Both Ends.
Plastic H Plugs, Receiving End
Plastic H Plugs, Both Ends
No Lubrication
No End Plugs
No Lubri-cation
2-SPs. 48"-6" Bol. D. Pe.
RMC Plastic Joint Packing (New Formula)
1. North 30 Joints with Middle 12 in. Length Omitted.
2. Next 60 Joints Identical to Item I except Brush Petrolatum (Dark) on Middle 12 in. of Joint.
3. South 45 Joints Packed Solid.
1-SP. 33-6" I Bms.
Sig. Br.
First Spray application was made July 29, 1953.
Second spray application 8-5-54
Third spray application 8-10-55
* Sec. 3, Brush Coat, Dixon's Lubricant to 7-29-53
Sec. 10, Brush Coat, Farbertite to 7-29-53
Grease brushed on rail only
Grease brushed on rail and joint bars

Fig. 1. – Rail Joint Lubrication Service Test in I.C.R.R. Northward Main Track Between Chebanse and Danforth, Ill.

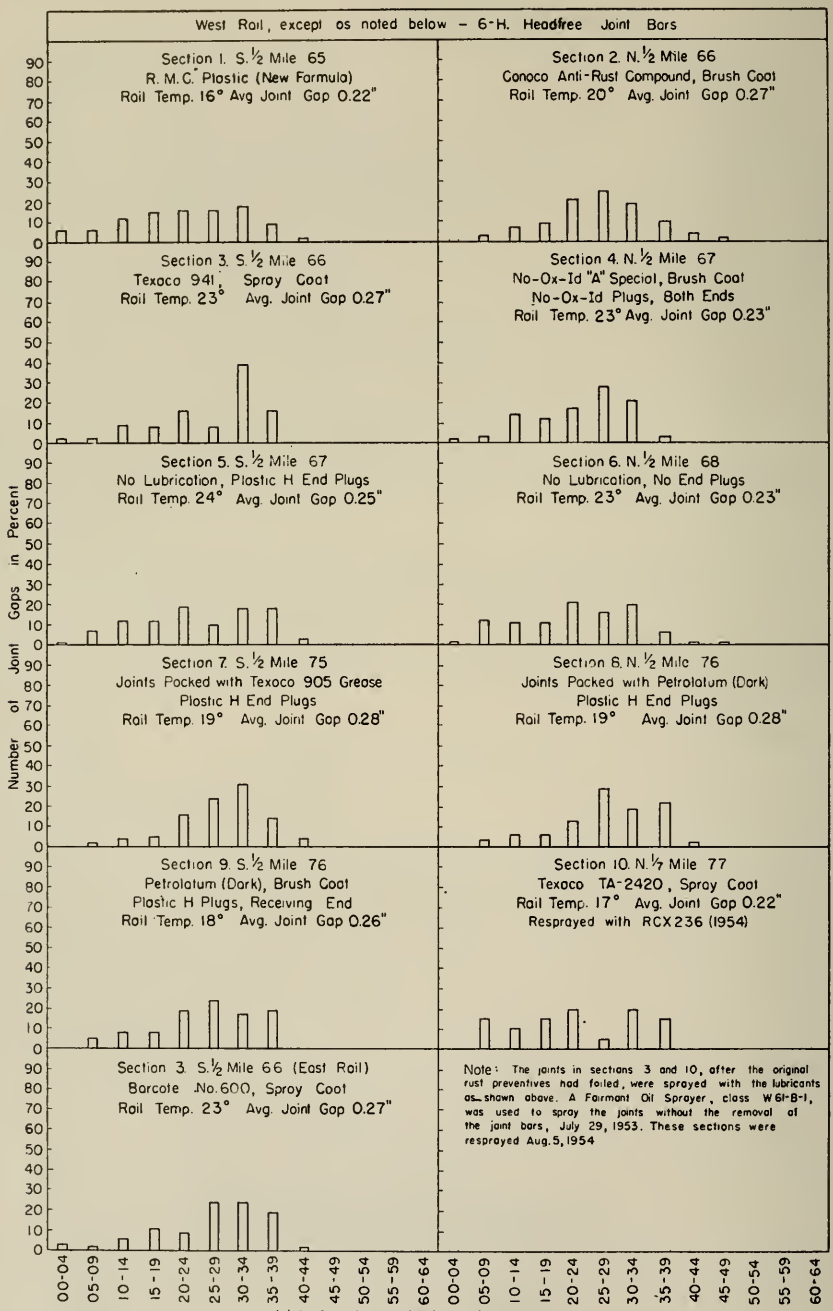

West Rail, except as noted below – 6-H. Headfree Joint Bars
Section 1. S. ½ Mile 65
R. M. C. Plastic (New Formula)
Rail Temp. 16° Avg Joint Gap 0.22"
Section 2. N. ½ Mile 66
Conoco Anti-Rust Compound, Brush Coat
Rail Temp. 20° Avg. Joint Gap 0.27"
Section 3. S. ½ Mile 66
Texaco 941, Spray Coat
Rail Temp. 23° Avg. Joint Gap 0.27"
Section 4. N. ½ Mile 67
No-Ox-Id "A" Special, Brush Coat
No-Ox-Id Plugs, Both Ends
Rail Temp. 23° Avg. Joint Gap 0.23"
Section 5. S. ½ Mile 67
No Lubrication, Plastic H End Plugs
Rail Temp. 24° Avg. Joint Gap 0.25"
Section 6. N. ½ Mile 68
No Lubrication, No End Plugs
Rail Temp. 23° Avg. Joint Gap 0.23"
Section 7. S. ½ Mile 75
Joints Packed with Texaco 905 Grease
Plastic H End Plugs
Rail Temp. 19° Avg. Joint Gap 0.28"
Section 8. N. ½ Mile 76
Joints Packed with Petrolatum (Dark)
Plastic H End Plugs
Rail Temp. 19° Avg. Joint Gap 0.28"
Section 9. S. ½ Mile 76
Petrolatum (Dark), Brush Coat
Plastic H Plugs, Receiving End
Rail Temp. 18° Avg. Joint Gap 0.26"
Section 10. N. ½ Mile 77
Texaco TA-2420, Spray Coat
Rail Temp. 17° Avg. Joint Gap 0.22"
Resprayed with RCX 236 (1954)
Section 3. S. ½ Mile 66 (East Rail)
Barcote No. 600, Spray Coat
Rail Temp. 23° Avg. Joint Gap 0.27"
Note: The joints in sections 3 and 10, after the original rust preventives had failed, were sprayed with the lubricants as shown above. A Fairmont Oil Sprayer, class W61-B-1, was used to spray the joints without the removal of the joint bars, July 29, 1953. These sections were resprayed Aug. 5, 1954
Number of Joint Gaps in Percent
0 10 20 30 40 50 60 70 80 90
00-04 05-09 10-14 15-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64
Joint Gap in Hundredths of an inch

Fig. 2. Joint Gap Measurements for Rail Joint Lubrication Test January 28, 1955
I.C.R.R. Chebanse to Danforth, Ill.

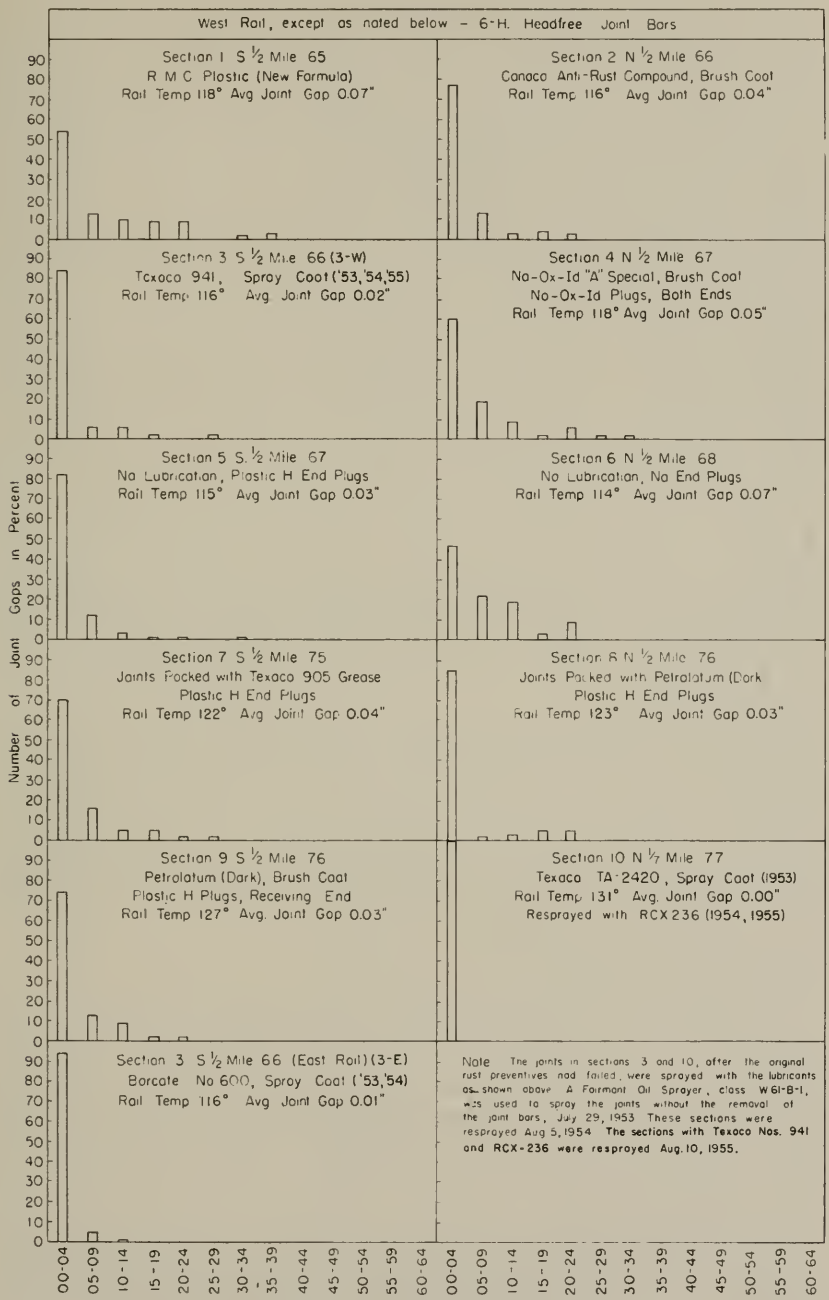

West Rail, except as noted below – 6-H. Headfree Joint Bars
Section 1 S ½ Mile 65
R M C Plastic (New Formula)
Rail Temp 118° Avg Joint Gap 0.07"
Section 2 N ½ Mile 66
Conoco Anti-Rust Compound, Brush Coat
Rail Temp 116° Avg Joint Gap 0.04"
Section 3 S ½ Mile 66 (3-W)
Texaco 941, Spray Coat ('53,'54,'55)
Rail Temp 116° Avg Joint Gap 0.02"
Section 4 N ½ Mile 67
No-Ox-Id "A" Special, Brush Coat
No-Ox-Id Plugs, Both Ends
Rail Temp 118° Avg Joint Gap 0.05"
Section 5 S ½ Mile 67
No Lubrication, Plastic H End Plugs
Rail Temp 115° Avg Joint Gap 0.03"
Section 6 N ½ Mile 68
No Lubrication, No End Plugs
Rail Temp 114° Avg Joint Gap 0.07"
Section 7 S ½ Mile 75
Joints Packed with Texaco 905 Grease
Plastic H End Plugs
Rail Temp 122° Avg Joint Gap 0.04"
Section 8 N ½ Mile 76
Joints Packed with Petrolatum (Dark)
Plastic H End Plugs
Rail Temp 123° Avg Joint Gap 0.03"
Section 9 S ½ Mile 76
Petrolatum (Dark), Brush Coat
Plastic H Plugs, Receiving End
Rail Temp 127° Avg. Joint Gap 0.03"
Section 10 N ½ Mile 77
Texaco TA-2420, Spray Coat (1953)
Rail Temp 131° Avg. Joint Gap 0.00"
Resprayed with RCX 236 (1954, 1955)
Section 3 S ½ Mile 66 (East Rail) (3-E)
Borcote No 600, Spray Coat ('53,'54)
Rail Temp 116° Avg Joint Gap 0.01"
Note The joints in sections 3 and 10, after the original rust preventives had failed, were sprayed with the lubricants as shown above A Fairmont Oil Sprayer, class W 61-B-1, was used to spray the joints without the removal of the joint bars, July 29, 1953 These sections were resprayed Aug 5, 1954 The sections with Texaco Nos. 941 and RCX-236 were resprayed Aug. 10, 1955.
Number of Joint Gaps in Percent
00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
Joint Gap in Hundredths of an inch

Fig 3 Joint Gap Measurements for Rail Joint Lubrication Test, July 7, 1955
I C R R Chebonse to Danforth, Ill.

The fact that section 10 had 100 percent of the joints in the first increment is not significant, because the section includes 40 joints and only 20 joints in 1 rail were measured. Excluding sections 3–W, 3–E and 10 that were first sprayed in 1953 (Fig. 3), sections 8 and 5 had the larger percentage of joints in the first increment. Section 5 had end plugs without lubrication. Section 6 without lubrication or end plugs and Section 1 with grease cakes, had the smaller percentage of joints in the first increment. It is apparent that factors other than lubrication greatly influence the pattern of rail gaps. It is believed that the difference in the rail gap patterns of sections 5 and 6 cannot be attributed to the end plugs used in Section 5. For the sprayed sections, 3–E and 3–W, the former, with Leadolene Barcote No. 600, had a little better rail gap pattern in the summer (Fig. 3). However, in this ½ mile of track, the east rail may have been laid tighter. There was little difference in the rail gap uniformity of these two sections in the last winter (Fig. 2). It was shown in previous progress reports that a moderate improvement in rail gap uniformity was effected by spraying the inside of the joints. Originally, in sections 2, 3, 4 and 9, the preservatives were brushed on both the rail and joint bars in the north half of each section and on the rail ends only in the south half. A study of the rail gap pattern in each half of each section for the 5-year period developed that there were no significant differences in the uniformity of the rail gap with respect to the two methods of brush coat application. In the appraisal of the rail gap patterns, as well as other factors, attention should be directed to (1) that the northward main had adequate rail anchorage, and (2) the track had about 15 percent reversed movements. The rail was anchored with 10 grip-type anchors per rail to resist rail creepage northward and 4 anchors for resisting rail movement in the opposite direction. The southward anchors were not boxed against the ties having the northward anchors.

Joint Bar Pull-In

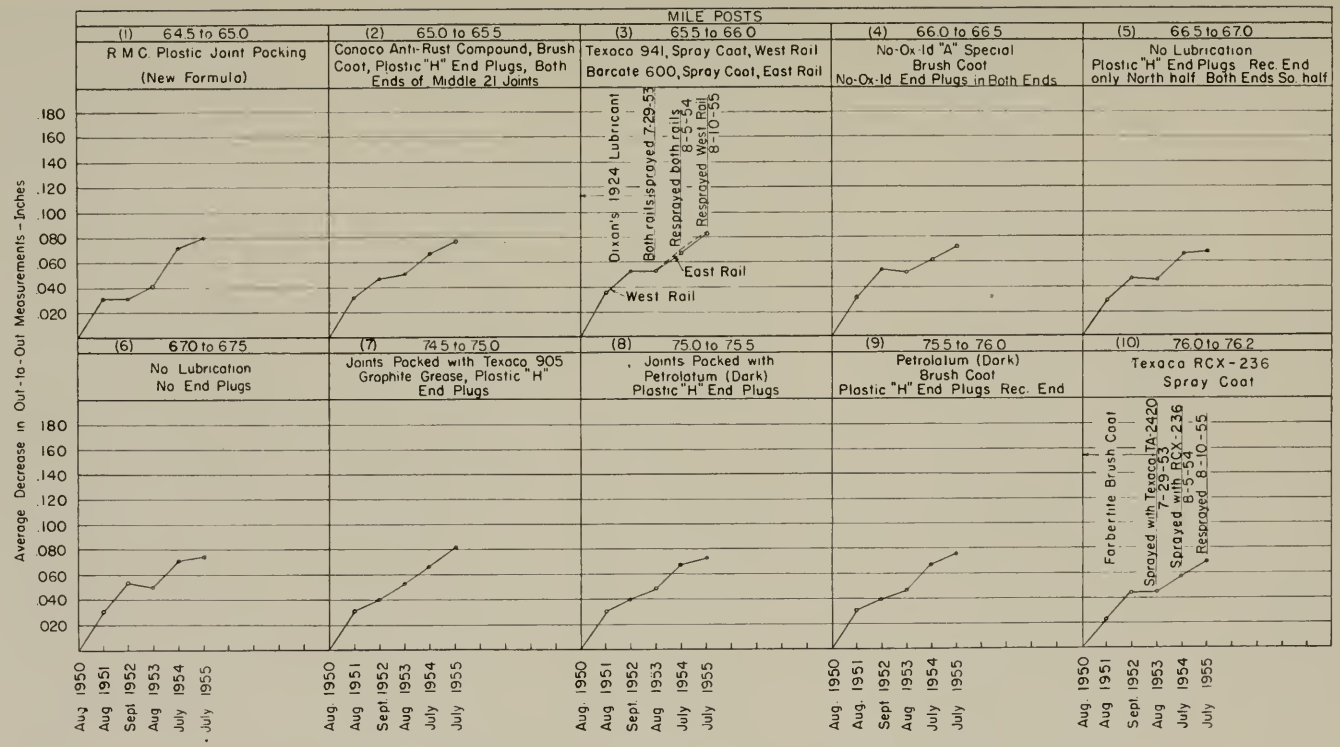
The joint bar pull-in measurements are shown in graphical form in Fig. 4. The average pull-in for all test sections in the 5-year period varied from 0.068 in to 0.082 in, with an average of 0.075 in, or about 0.015 in per year. In the sections having a brush coat applied in one-half of the joints on the rail only, and on both the rail and the joint bars on the other joints, there were no significant differences in the total wear of the joints. The total pull-in of the joints without lubrication compared favorably with some of the sections having a metal preservative. There was no indication that the sprayed joints had any reduction in joint wear.

Maintenance of Way Report

For the last service period the IC reported one loose bolt in the north half of section 4. There were no bolts broken or stripped joints. During the service period of approximately 5 years, a total of only 3 bolts were found broken and 2 others were loose. No joints were pulled in two. Each autumn the bolts are retightened with power track wrenches. The bolts in 4.58 miles of track for a period of 5 years have required little maintenance between the annual bolt tightenings. In this test a loose bolt is one that has no tension.

Inspection of End Plugs

Each summer all of the Texaco Plastic H end plugs are inspected by the research staff, AAR. The No-Ox-Id end plugs in section 4 failed by slumping during the first summer. The test includes 1740 Plastic H end plugs as follows: 980 with square ends in sections 7 and 8, and 760 with beveled ends in sections 2, 5 and 9. Thirty-five, or 3.6



Note Out-to-Out measurements taken at top and bottom of ends and middle of all joint bars in west rail, except as noted Values shown are the mean of top and bottom of bars.

Fig. 4 Average Pull-in of Joint Bars, I.C.R.R., Chebonse to Danforth, Illinois

percent, of the square plugs, and 90, or 11.8 percent, of the beveled plugs had worked out of the joints. The square-end plugs had better retention and required a little less material for the application.

Inspection of Dismantled Joints

On July 13, 1955, the subcommittee conducted its annual inspection of the tests on the IC by observing the condition of 15 dismantled joints in 11 test sections. The inspection group included 5 AREA members, 2 of whom were members of the Track committee (one of whom was the subcommittee chairman), 7 representatives of 5 suppliers, and 4 others, making a total of 16. This was the third successive year of reasonably good attendance. The photographer of the Burlington Railroad took the photographs for the research staff, and the Association is indebted to the Burlington for having the assistance of their capable photographer. Figs. 5 to 19, incl., are composite photographs showing the bottoms of the bars as well as the tops. Figs. 20 to 25, incl., were taken on August 10 and 11, 1955, in connection with spraying the joints in 5 sections. Prior to the inspection, the weather had been hot and dry.

Figs. 5 to 7, incl., show the condition of one joint for each of the three methods of application of the RMC plastic joint packing. Both of the joints in Figs. 5 and 6 had the middle cakes omitted, but in the latter joint a brush coat of petrolatum (dark) was applied to the rail ends where the cakes were not used. These two joints had appreciably more lubrication on the bottom fishings of the rail and bars than the joint packed solid (Fig. 7). The outer ends of the grease cakes had become dry and hard, and apparently the exuded oil from the inner portion of the cakes had built up against the bottoms of the bars and had flowed on the rail fishing into the zone without the cakes. Except on the rail base the rail web and upper fillets were quite dry and corroded in the joint (Fig. 5) without the petrolatum. There was less corrosion in the joint (Fig. 6) where the petrolatum was brushed on, although there was some corrosion in the upper rail fillets. In the joint packed solid (Fig. 7) the cakes had dried out and adhered to the joint bars when removed. This joint was much drier than the other two and had little fresh bleeding in evidence. The joint in Fig. 5 had the most corrosion in the middle foot, but there was no serious pitting in any of the joints with the grease cakes. There was a definite advantage in applying the brush coat of petrolatum in the middle foot, but the economy of this added protection is doubtful, because the most serious deficiency of the grease cakes from the standpoint of preserving joints is at the upper fishings. The grease cakes provided good protection to the bolts, although the middle bolts, where the cakes had been omitted, were drier and had some corrosion.

The sections having brush coat protection of a preservative are represented in Figs. 8, 9 and 16 in sections 2, 4 and 9, respectively. Of the three brush coat sections, the joint in section 9 (Fig. 16) with petrolatum (dark) and Texaco Plastic H receiving end plugs had the poorest protection. The lubricant was in the most deteriorated condition except in the end of the joint next to the plugs (on the left in the figure). In all three sections most of the fishing areas were dry. The heat from the rail end hardening had caused the greases to be melted off the middle one-third of the joints, except that the field side of the rail web of the joint in Fig. 9, with No-Ox-Id "A" Special, had more protection in that area. However, on the same joint there was little grease on the rail web on the gage side. In the joints where there were rust slabs in the lower rail fillets, the slabs were soft. All of the end plugs of the joint in section 4 (Fig. 9) had worked out. It will be recalled that the No-Ox-Id end plugs slumped the first summer because of the heat.

Because of the reversed movements, the joints in section 9 with receiving end plugs would have had better protection if both ends had been plugged. Because of the deteriorated condition of the petrolatum compounds, it is planned to discontinue the brush coat sections, except for the middle 21 joints in section 2 having plastic H plugs in both ends. Inspection of those joints will be continued, because in last year's inspection it was found that the end plugs had protected the brush coat of Conoco Anti-Rust Compound. Generally, the bolts were in good condition, but a few of the end bolts were corroded more. All of the bolt threads were in good condition.

Sections 5 and 6, without lubrication, are covered by Figs. 10, 11 and 12. Section 5 has receiving end Plastic H plugs in the north half, while in the south portion both ends of the bars were plugged. There was a small amount of spray oil in these joints, which had entered the joints when the IC sprayed the outside of the bars with their self-propelled spray car three or four years ago. In section 5 the joints with receiving end plugs (Fig. 10) had a little debris blown in by the reversed movements. In the joints with both ends plugged (Fig. 11) there was no debris, and some of the mill scale was left on the rail web. The other joint (Fig. 10) with receiving end plugs had some mill scale left on the rail adjacent to the plug, but about two-thirds of the length of the rail in the joint was covered with a thin layer of corrosion. This joint had some rust slabs under the plugs in the lower rail fillets, which might become hard in the future and reduce the available take-up of the headfree bars. The joint with both ends plugged had some rust under the receiving end plugs only. There was no moisture in these joints. There was less corrosion in the joint with both ends plugged. However, the corrosion in the joint with receiving end plugs only was a thin layer of finely divided rust, without pitting, and was judged not to be detrimental to the life of the rail. The joint inspected in section 6, without lubrication or end plugs (Fig. 12), was relatively free of debris and had no hard rust slabs in the lower rail fillets. With reversed movements, the receiving end plugs created a trap to hold the debris in the joint. In this test there was no evidence of brine corrosion, and it is judged that the benefits derived by the use of end plugs without lubrication was uneconomical. Section 6 will be continued for controls.

Figs. 13, 14 and 15 show the condition of joints packed with a grease and plastic H end plugs. Two joints were inspected in section 7 with Texaco No. 905 graphite grease because, in removing the bars, the grease was pushed off the rail web (Fig. 13). On the basis of the joint in Fig. 14, it was estimated that two-thirds of the graphite grease was still in the joint. The joints in section 7 have had the best protection provided in this test. The upper rail fillets were free of corrosion, and the bars had a liberal amount of lubrication on the fishings. The bolts were well preserved. There were no rust slabs at the end plugs. The joints packed with petrolatum (dark) had the second best protection from corrosion (Fig. 15). As can be observed from the figure, most of the petrolatum had melted and run out of the joint. The joint had some lubrication on the fishings but this was less than in section 7. The bolts were well greased and there was a little corrosion on the upper rail fillets. No rust slabs were found at the end plugs. Sections 7 and 8 will be continued in the test to determine the service life of this method of preserving the joints and the bolts.

The condition of the joints in sections 3 and 10, after being sprayed two successive summers (1953 and 1954), is shown in Figs. 17, 18 and 19. There was not much covering by the lubricants left in these joints, except that the rail web in the joint of section 3–E (Fig. 18), with Leadolene Barcote No. 600, had the best coating. The coating shown in the figure for the field side of the rail was better than on the gage side. It was decided

to respray section 3–W with Texaco No. 941 and section 10 with Texaco No. RCX–236, and to determine the protection Barcote No. 600 would provide in the second year, after the joints had previously been sprayed with the same material in 1953 and 1954. In 1954, because the oil sprayer had insufficient heat to atomize the RCX–236 properly, it is judged the condition of this heavier preservative might have been better. With warmer weather and a new type of nozzle, the RCX–236 had good atomization when sprayed on the joints in August 1955 (Fig. 21).

Spray Method for Joint Preservation

Investigation of this importance phase of the assignment was begun in July 1953 by the application of three metal preservatives to the joints in original sections 3 and 10, where the brush coat protection had failed by oxidization and flaking off the rail. At that time the joints in the west and east rails of section 3 were sprayed the first time with Texaco No. 941 and Leadolene Barcote No. 600, respectively. Each of the above sections was resprayed with the same preservative in August 1954. The joints in section 10 were sprayed with Texaco No. TA–2420 in 1953 and with Texaco No. RCX–236 in 1954. Preservative TA–2420 was essentially Texaco No. 55 with a wetting agent added. RCX–236 is a modification of TA–2420.

On August 10, 1955, section 3–W was sprayed the third time with Texaco No. 941, and section 10 was sprayed again with RCX–236. In section 3–E with Barcote 600, the joints were not sprayed in 1955 in order to determine what protection would be provided for the rail in the second year after the last spray coat applied in 1954. The last inspection had developed that there was a thicker coat of Barcote 600 left on the rail web than in the case of the two Texaco products. Compare Fig. 18 with Figs. 17 and 19.

In August 1955, three different spray materials were applied to the joints in the 1944—131 RE rail of the southward main on Miles 75 and 76. This track also has reversed movements. The 6-hole headfree joint bars in the 1944 rail had not been sprayed or otherwise lubricated on the inside since 1944. The joint bars had been removed and reversed in the fall of 1954. Four additional test sections were set up in the west rail at the above location as follows: section 11–W, north half of Mile 75, no lubrication for controls; section 12–W, south half of Mile 75, Texaco No. 1965; section 13–W, north half of Mile 76, Conoco Rail Joint Spray No. 151; and section 14–W, south half of Mile 76, No-Ox-Id No. 100. Texaco No. 1965 is similar to Texaco No. 941, except a rust inhibitor was added to the former. Conoco No. 151 is a thin black spray material with a wetting agent and rust inhibitors. It has rapid penetration and flowing qualities for unfreezing joints. This formulation was developed by the manufacturer after several years of exploratory work in the field. No-Ox-Id No. 100 was developed by the Dearborn Chemical Company for spray application on bridges, track joints, etc. This material is petrolatum based, has a rust inhibitor and a wetting agent, and sufficient solvent to obtain a spraying consistency with spraying equipment of a suitable design to supply adequate heat and pressure to the material. This spray material has less flowing and penetrating qualities than the thinner materials, but provides a thicker coating on the rail, which may give a longer service life for protecting the rail from corrosion.

On August 10 and 11, 1955, two of the old sections and the three new sections in the 1944 rail were sprayed with the same Fairmont oil sprayer, Model W 61, Series B, as used in previous years. A different type of nozzle was used this year, which gave excellent coverage inside the joints. These nozzles were of the flat-jet type, manufactured by the Spraying Systems Company and bearing their No. ⅛ P3504, with an orifice of

3/64 in. This design diverts the spray 40 deg upward and develops a horizontal spray angle of 41 deg at 100 psi. All of the spray materials were applied by inserting the nozzle behind the joint bars to the second bolt and also by spraying the top of each bar. This year it was impossible to regulate the heat and pressure of the spray material. However, all of the materials were atomized properly, except that the application of the No-Ox-Id No. 100 could have been improved by having more heat and pressure. To assist in spraying the No-Ox-Id No. 100 and RCX-236 (the heavier materials), they were placed in a heated building the night before the spraying operation. This precaution would not have been necessary if another design of machine had been available.

An accurate check of the quantity of each type of spray material was made. The quantity of material used in pounds per joint was as follows: Texaco No. 941, 0.8 lb (2.0 in 1954); RCX-236, 1.0 lb (1.2 in 1954); Texaco No. 1965, 1.3 lb; Conoco No. 151, 1.1 lb; and No-Ox-Id No. 100, 0.6 lb. Figs. 20 to 24, incl., show the coverage obtained on the inside of the joints immediately after the spraying operation. Good coverage on the rail web and fillets was obtained with all five of the spray materials. The fishings were covered well with the thinner materials, but in the case of No-Ox-Id No. 100, the coverage was the poorest on the fishings. Coverage of the fishings by RCX-236 rated second to the thinner materials. By having more heat and pressure, possibly the two last-mentioned materials would have better flowing qualities.

Fig. 25 shows the corrosion within one of the 1944 rail joints before spraying. Most of the traffic is to the left in the picture, and the zone of the worst corrosion can be observed on the right or leaving rail end near the receiving end of the joint, which had the bars previously reversed. The gage side of the rail (not shown in the photograph) was corroded to a much lesser extent. There was some pitting by the corrosion on the field side of the leaving rail end, but it was not serious. Neither of the main tracks showed evidence of much brine corrosion. The receiving end of the outside joint bar, prior to its reversal, was corroded much more than on other areas of the bars. On the base of rail there were the remains of some Texaco No. 45 metal preservative that entered the joint when the joint was sprayed on the outside with a self-propelled oil sprayer a few years ago.

Because the joint bars had been reversed in the fall of 1954, it is judged that the problem of unfreezing the joints in the 1944 rail will be, by far, less difficult than if the joints had not been dismantled.

Conclusions

1. The chief benefits derived from the rust preventives remaining in the 1950 installations were: reducing corrosion of the rail and joint bars; and preventing the formation of hard rust slabs in the lower rail fillets, which can shorten the service life of the headfree bars by reducing the available take-up.

2. The original preservatives did not effect a reduction in the joint wear and had little influence on the uniformity of rail gap. Items 1 and 2 were also developed from the 6-year service test conducted on the Burlington Road near Earlville, Ill.

3. The brush coat application of petrolatum (dark) and the two petrolatum-based preservatives in sections 2 and 4 were seriously damaged by the heat left from the rail end hardening. Rail end hardening of new rail in the field should be avoided, if possible.

4. During the 5-year period there were no stripped joints, and only 5 bolts had to be replaced or retightened between annual retightening of the bolts with power wrenches. In this test there was 1 mile of track without lubrication. There was no extra

joint maintenance of bolts in these 2 sections. It is judged that the foregoing performance can be largely attributed to the adequate anchorage provided and annual tightening of the bolts with power wrenches.

5. The square end plugs had better retention than the beveled ones and required less Texaco Plastic H. The No-Ox-Id end plugs were unsatisfactory because of their instability in summer heat. Because of the reversed movements, receiving end plugs only, afforded little protection to the joints and the brush coat application. With only moderate corrosion in this test, the use of end plugs in both ends of the joints was not detrimental to the rail or joint bars, except that where no lubrication was applied there was a little tendency for rust slabs to form in the lower rail fillets behind the plugs. In this test end plugs were of little benefit in the joints without lubrication. However, joints having a brush coat application with both ends plugged will have a longer life of the original preservative. This will be developed in the future.

6. Of the brush coat applications, petrolatum (dark) provided the poorest protection against corrosion. An accurate evaluation of a brush coat of No-Ox-Id "A" Special vs Conoco Anti-Rust Compound cannot be made, because the No-Ox-Id end plugs, even though they slumped in the first summer, provided some protection to the preservative in the joints. Further, the detrimental effect of the rail end hardening heat on the two petrolatum-based compounds also complicated a fair appraisal of them. In the AAR—Burlington Road test near Earlville, Ill., No-Ox-Id "A" Special as a brush coat without end plugs and petrolatum (dark) gave the best service performance over a 5-year period. In sections 2, 4 and 9, the original brush coat applications were made in two ways. For the first three years in the joints where both the bars and the rail ends were greased, there was, in general, more lubrication on the rail and bars and also less corrosion than in the joints where the rail ends only were greased. Because the application was made about 20 min after the rail ends were hardened, the heat left in the joint bars caused most of the petrolatum greases to run off throughout their length, as well as on the rail ends to beyond the first bolt holes. In this test, because the low-melting-point compounds were adversely affected by the heat, the benefit of the dual application was minor. However, if the joints had been at a normal temperature, it is judged that the joints with the dual application would have been preserved better.

7. Joints packed with Texaco No. 905 graphite grease were in the best condition as to lubrication and the arresting of corrosion. The economy of this method of rail joint preservation depends on the service life, which has not been determined.

8. The RMC plastic joint packing preserved the track bolts well and provided protection from the weather, but was deficient in keeping the upper half of the joint lubricated, and also permitted corrosion on critical areas of the rail near the rail ends and the first bolt hole. In the dismantled joint packed solid with the grease cakes, the packing was dry after 5 years of service and had lost most of its lubricating capacity. Where the middle cakes were omitted, the end cakes served well as end plugs, and exuded more oil than in joints packed solid. It is judged that the corrosion on the rail ends without the middle cakes was less harmful than in the joints packed solid.

Fig. 5—North portion section 1. RMC plastic joint packing with no lubricant applied where the middle cakes were omitted.

Fig. 6—Middle portion section 1. RMC plastic joint packing with brush coat of petrolatum (dark) on rail where middle cakes were omitted.

Fig. 7—South portion section 1. Joint packed solid with RMC plastic joint packing.

Fig. 8—North portion section 2. Brush coat of Conoco anti-rust compound on rail and joint bars.

Fig. 9—North portion section 4. Brush coat of No-Ox-Id "A" Special on rail and bars with No-Ox-Id end plugs.

Fig. 10—North portion section 5. No lubrication. Plastic H plugs in receiving end.

Fig. 11—South portion section 5. No lubrication. Plastic H plugs in both ends.

Fig. 12—Section 6. No lubrication or end plugs.

Fig. 13—Section 7. Packed with Texaco 905 graphite grease and Plastic H end plugs.

Fig. 14—Section 7. Packed with Texaco 905 graphite grease and Plastic H end plugs.

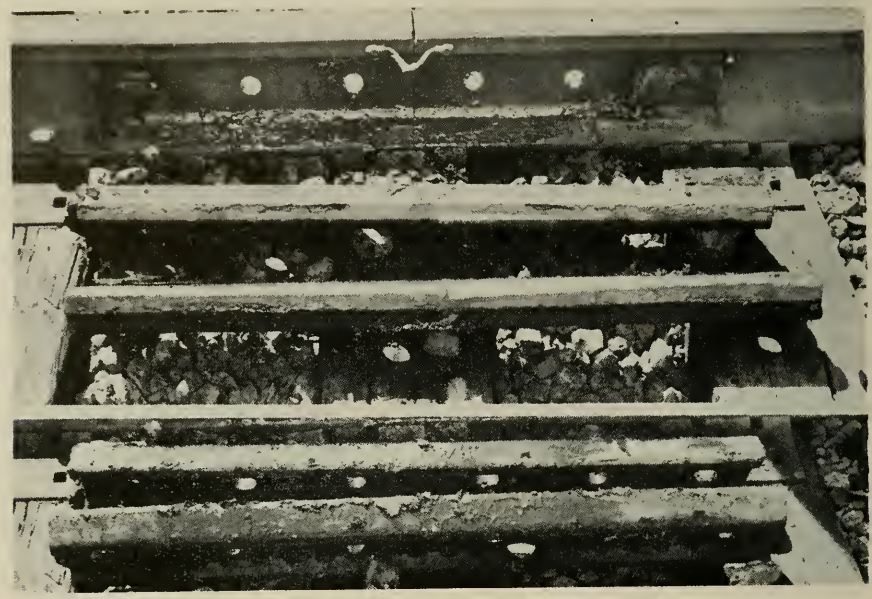


Fig. 15—Section 8. Packed with petrolatum (dark) and Plastic H end plugs.

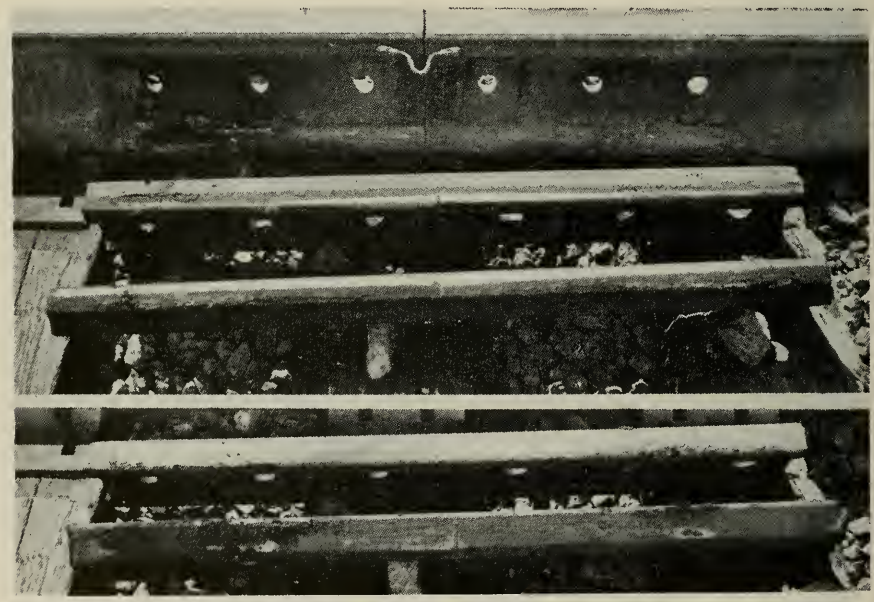


Fig. 16—South portion section 9. Brush coat of petrolatum (dark) on rail only and Plastic H receiving end plugs.

Fig. 17—West rail, section 3. Spray coat of Texaco 941.

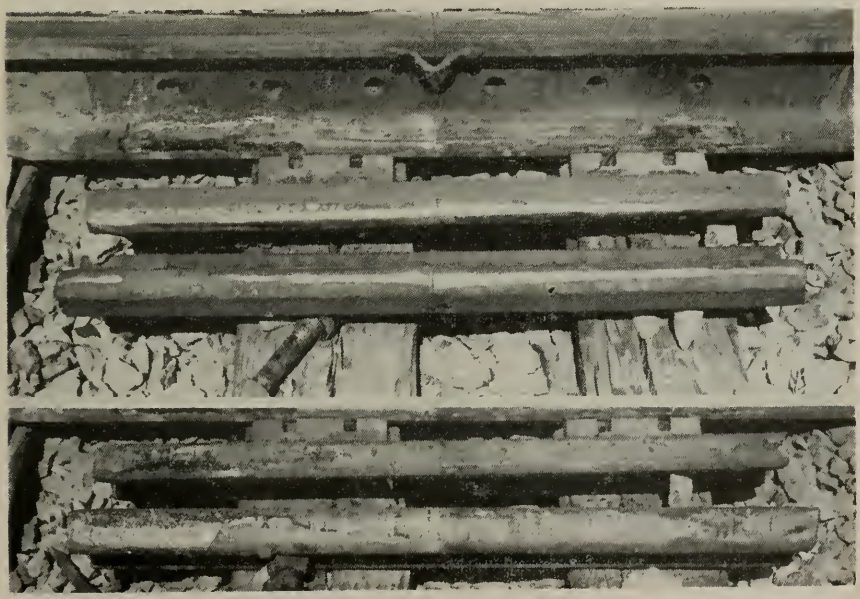



Fig. 18—East rail, section 3. Spray coat of Leadoline Barcote No. 600.

Fig. 19—Section 10. Spray coat of Texaco RCX–236.

Fig. 20—West rail, section 3. Third spray coat of Texaco No. 941 (15 min after application).

Fig. 21—Section 10. Second spray coat of Texaco RCX–236 (15 min after application).

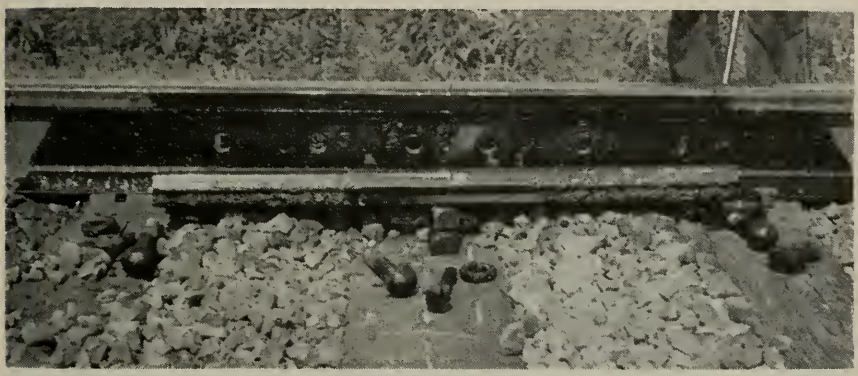


Fig. 22—Section 12–W. First spray coat of Texaco No. 1965 on 1944 rail (15 min after application).

Fig. 23—Section 13–W. First coat of Conoco rail joint spray No. 151 on 1944 rail (15 min after application).

Fig. 24—Section 14–W. First spray coat of No-Ox-Id No. 100 on 1944 rail (15 min after application).

Fig. 25—Condition of a joint in 1944–131 RE rail of the southward main track prior to the spray application.

Part 2

LABORATORY BRINE CORROSION TESTS OF METAL PRESERVATIVES USED IN RAIL JOINTS

The purpose of this laboratory brine corrosion test was to evaluate 11 metal preservatives as to their effectiveness in arresting corrosion in the presence of brine.

The following compounds, which have been used for preserving rail joints, were included in these tests:

*1. Texaco rail joint lubricant No. 941 (a)
2. Texaco Crater 2–X
*3. Brooks Oil Company Leadolene Barcote No. 600 (a)
*4. Brooks Oil Company Leadolene Barcote No. 900
5. Texaco No. 904 graphite grease (b) (a)
*6. Brooks Oil Company Leadolene No. 325
7. Armite Laboratories Armite Compound No. 500
*8. Texaco No. RCX–236 (a)
9. Dearborn Chemical Company No-Ox-Id "A" Special (a) (b)
10. Stanolind petrolatum (dark) (a) (b)
11. Continental Oil Company anti-rust compound (a)

* Consistency suitable for spray application on rail and joints.
(a) Used in AAR–IC service tests.
(b) Used in AAR–CB&Q service tests.

Most of the above listed metal preservatives have been described in previous reports on this assignment and are well known to those concerned with rail joint preservation, except No. 7—Armite Compound No. 500. This preservative, a product of Armite Laboratories, is basically a pure metallic lead compound. The finely divided lead of colloidal consistency is in permanent suspension. The compound is a high-pressure lubricant and is too expensive for use in track, the cost being approximately $0.60 per lb.

The greases were placed on coupons of mild steel which had been prepared through pickling and degreasing techniques. The clean coupons, measuring 3 by 1½ by ⅛ in, had a plastic film cover on one end, leaving an area for exposure measuring 2 by 1½ by ⅛ in, equivalent to 6.7 sq in. The quantity of grease applied or adhering to a coupon was based on the judgment of the operator and the particular viscosity of the grease in question. Application was made at room temperature (80 deg F).

The exposure cycle for the accelerated corrosion test consisted of allowing the coupons to stand at room temperature for 3 hr following application of grease, after which the coupons were immersed in a 5 percent brine solution for 15 min. The coupons were removed from the solution and allowed to drain prior to being placed in an atmosphere of 40 percent relative humidity for 7 hr at 120 deg F. These conditions might occur during the day in mild weather when the sun was out. The coupons again were immersed in the brine solution for 15 min, allowed to drain, and then placed in an atmosphere of 100 percent relative humidity at 120 deg F for approximately 16.5 hr, or until the next morning. This cycle was repeated until Wednesday of each week, when the coupons were placed in an oven at a temperature of 140–150 deg F for 6 hr. This temperature represents extreme exposure during the summer. The coupons were allowed to reach room temperature over a 1-hr period, then dipped again in the brine solution for 15 min and placed in the 100 percent relative humidity atmosphere overnight at 120 deg F. Over

the weekends the coupons were placed in a freezer at temperatures ranging from 0 to — 15 deg F. The above cycle was repeated over periods of 3 and 6 months.

In the lower part of Table 1 for the 6-month exposure, there were 3 preservatives in the best group, viz., Texaco 904 grease, Armite Compound No. 500, and Conoco Anti-Rust Compound. These have specimens Nos. 5, 7 and 11, respectively, and each had about 2½ percent loss of weight of the coupons from corrosion, whereas the loss from corrosion of those in the poorest group ranged from 23.4 to 27.3 percent. Fig. 26 includes a view of one edge of each of the 11 coupons, and it will be observed that specimens 5, 7 and 11 had a cleaner appearance and less corrosion than the other coupons. A supplementary test was made for a 25-day period to determine the loss in weight of the preservatives caused principally by the temperature cycle. These control specimens were tested in the same manner as the other specimens, except they were not dipped in brine. The results of the supplementary tests are shown in the following table.

Number and Name of Preservative	*Weight of Preservative in Grams*			*Percent Loss of Preservative*
	Initial	*Final*	*Difference*	
1. Texaco rail joint lubricant No. 941	0.09	0.0	0.09	100 (approx.)
2. Texaco Crater 2-X	1.22	0.02	1.20	98.7
3. Barcote No. 600	0.56	0.35	0.21	37.5
4. Barcote No. 900	0.40	0.26	0.14	35.7
5. Texaco No. 904 grease	*2.25*	*2.00*	*0.25*	*11.4*
6. Leadolene Barcote 325	0.34	0.03	0.31	91.3
7. Armite Compound No. 500	*4.07*	*0.70*	*3.37*	*82.7*
8. RCX-236	0.21	0.01	0.20	97.0
9. No-Ox-Id "A" special	1.42	0.21	1.21	85.5
10. Stanolind petrolatum (dark)	1.55	0.06	1.49	96.4
11. Conoco anti-rust compound	*1.79*	*1.79*	*1.43*	*79.8*

It will be observed that the percentage of preservatives left on the coupons was not necessarily indicative of the quality of the protection from corrosion. In the best group of 3 compounds, Texaco No. 904 grease was high, with 88.6 percent retained as compared with 17.3 and 20.2 percent retained for specimens 7 and 11, respectively. Low viscosities of the respective products at room temperature were responsible for the low quantities of grease retained initially on specimens Nos. 1, 3, 4, 6 and 8.

It might be pointed out that Skorchelletti and Vasilyev in the Journal of Applied Chemistry of the USSR, in experiments somewhat similar to these, found a considerable solubility of oxygen in oil and grease. Prior to their work many people thought that a grease coating shielded a surface from both moisture and oxygen. This is not true. Oxygen dissolves more readily in grease than it does in water, and is capable of penetrating through a grease film. Moisture is always present, hence the combination is aggressive. However, where rust-inhibiting components are present, successful protection may be achieved.

Summary

While the best 3 compounds were very effective in arresting brine corrosion in the precisely controlled laboratory test, it was not possible to fully simulate service conditions, and the results obtained may be somewhat different in actual service for all lubricants tested. Texaco No. 904 grease has a melting point of approximately 190 deg F and was not affected like some of the other compounds with a lower melting point. In the rail joint lubrication test on the Burlington it was found that, as a brush coat, the Texaco No. 904 grease had weathered away seriously in 3 years. Armite Compound

TABLE 1. RESULTS OF LABORATORY BRINE CORROSION TESTS OF ELEVEN METAL PRESERVATIVES

Specimen No.	Lubricant	Initial Weight of Specimen	Weight of Applied Grease	Weight Loss of Specimen	Percent Loss	Rank
		Weight in Grams				
Three Months' Exposure						
1	Texaco Rail Joint Lubricant No. 941	70.4272	0.09	9.4968	13.5	4
2	Texaco Crater 2-X Comp.	74.1695	1.22	8.8921	12.0	4
3	Leadolene Barcote No. 600	71.2133	0.56	5.3214	7.48	3
4	Leadolene Barcote No. 900	66.5767	0.40	2.9204	4.38	2
5	Texaco No. 904 Graphite Grease	68.0695	2.25	0.2156	0.32	1
6	Leadolene No. 325	69.1778	0.34	8.8850	12.8	4
7	Armite Compound No. 500	68.3336	4.07	0.1727	0.25	1
8	Texaco No. RCX - 236	66.4458	0.21	7.8772	11.9	4
9	No-Ox-Id "A" Special	69.6848	1.42	2.2109	3.17	2
10	Stanolind Petrolatum (Dark)	68.3139	1.55	2.2245	3.25	2
11	Conoco Anti-Rust Compound	70.6544	1.79	0.3847	0.54	1
Six Months' Exposure						
1	Texaco Rail Joint Lubricant No. 941	70.8433	0.07	19.0787	26.9	3
2	Texaco Crater 2-X Comp.	69.0043	1.04	18.8554	27.3	3
3	Leadolene Barcote No. 600	67.0147	0.57	15.6683	23.4	3
4	Leadolene Barcote No. 900	72.1258	0.41	10.4283	14.4	2
5	Texaco No. 904 Graphite Grease	70.2361	2.07	1.7554	2.5	1
6	Leadolene No. 325	68.4922	0.30	18.6772	27.3	3
7	Armite Compound No. 500	72.1690	3.47	1.7914	2.5	1
8	Texaco No. RCX - 236	71.1946	0.28	18.3801	25.8	3
9	No-Ox-Id "A" Special	68.3182	1.50	10.2243	14.9	2
10	Stanolind Petrolatum (Dark)	68.2311	1.31	12.5073	18.3	2
11	Conoco Anti-Rust Compound	71.8220	1.86	1.8610	2.6	1

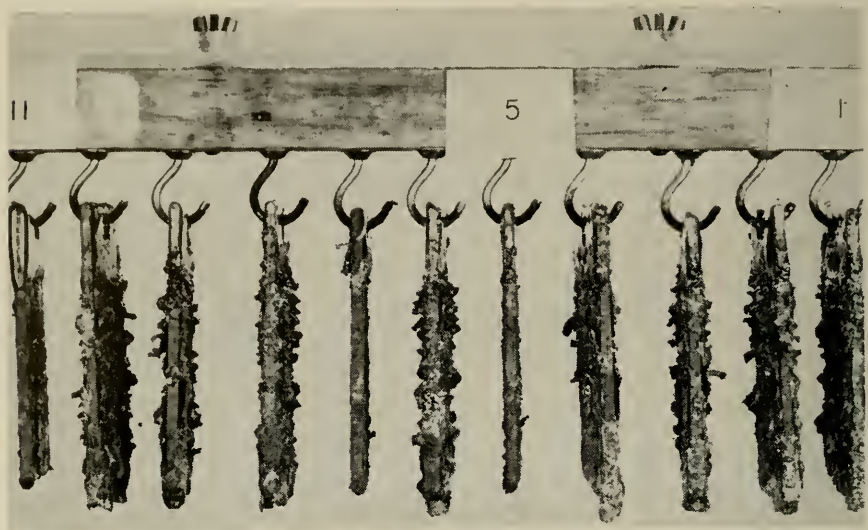


Fig. 26—Condition of coupons after 6 months of exposure in the laboratory brine corrosion test.

No. 500, as well as Conoco anti-rust compound, was adversely affected by the oven test. The price of Armite No. 500 makes it prohibitive for use in track. Conoco anti-rust compound has a moderate cost but will be affected by the summer heat as well as abrasion from the movement of sand caused by the faster traffic. This is a pilot test, and other preservatives will be tested at some future date. The results have been discussed informally with some of the manufacturers for the purpose of developing a low cost metal preservative that will arrest brine corrosion in joints and on the solid rail, as well as to resist the elements.

Acknowledgement

The Association is indebted to the Illinois Central for its cooperation and assistance in conducting the service tests and gratefully acknowledges the cooperation on the part of the suppliers that furnished the compounds for the laboratory and field tests.

Report on Assignment 8

Laying Rail Tight with Frozen Joints

J. B. Wilson (chairman, subcommittee), L. L. Adams, F. J. Bishop, M. C. Bitner, H. F. Busch, H. B. Christianson, C. A. Colpitts, W. E. Cornell, P. H. Croft, J. W. Fulmer, L. W. Green, A. B. Hillman, M. P. Oviatt, W. A. Schubert, G. R. Sproles, D. J. White.

This report, offered as information, describes a test installation of tight rail made by the Louisville & Nashville Railroad, which will be used by the committee to develop information on the relative economies of rail laid tight with high bolt tension and rail laid with normal expansion and bolt tension.

This investigation is being conducted by the AAR research staff under the general direction of G. M. Magee, director of engineering research. H. E. Durham, research engineer of track, has direct charge of the assignment and is being assisted by A. D. Van Sant, assistant research engineer track, and other members of his staff.

Foreword

Some railroads having a relatively large proportion of main track mileage with medium and sharp curvature do not believe that it will be wise to lay continuous welded rail because of the complications in transposing rails on the curves and the inconvenience and cost of relaying welded rail in secondary tracks. The objective of the committee is to conduct a service test on rail laid tight with high bolt tension and compare it with rail laid with normal expansion and bolt tension. The factors to be investigated are: (1) rail end batter, labor tamping up the joints and building up or grinding the joints, (2) pull-in or total joint wear of the joints, (3) the frequency of retightening of the bolts in tight vs normal joints, and (4) other costs, such as lining track at the joints, maintaining the rail anchors, bolts, signal bonds, and respacing ties.

Inspection of L&N Test

L. L. Adams, chief engineer, L&N, invited Subcommittee 8 and AAR representatives to examine a test of tight rail on September 7, 1955. The tight rail test section, about ⅞ of a track mile on tangent, had been laid with 132 RE rail, November 10 and 11, 1953, on Mile 225 and 226 of the single-track main line of the Lewisburg Subdivision, Birmingham Division, 40 miles south of Nashville, Tenn., near Chapel Hill, Tenn. The inspection party included 2 members of the Subcommittee 8, 5 representatives of the L&N, 7 representatives of the suppliers, and 2 members of the AAR research staff. After looking over the test and finding that all of the joints were closed and that most of them were in good condition with little or no chippnig, the subcommittee decided that this installation would be satisfactory for making a service test for comparison with the same number of joints in the normal rail in the vicinity of the tight rail. Although the rail was 22 months old and had carried approximately 22 million gross tons of traffic, it was the belief of the subcommittee that not having the data for the earlier part of the test would not be a handicap, but would actually save time in securing sufficient information for final conclusions.

Description of Test Section with Tight Rail

Before laying the tight rail, all necessary tie renewals were made and the track was given a general surfacing with slag ballast. In addition, 14-in tie plates for the new 132 RE rail were used to replace the 100 RE rail tie plates, and one rail was gaged out to accommodate the difference in the rail sections. The new 132 RE rail was provided with 6-hole headfree joint bars, 1⅛-in bolts and ⅝-in by 6-in cut spikes. The rail temperature ranged from 65 to 70 deg F when it was laid and anchored. The rail was placed with a rail crane and the joint bars were applied loosely. When approximately 10 rails had been laid, the rails were bumped on the ends to close the gaps. The middle bolts were wrenched tight and the other bolts were tightened to a normal tension. All bolts were then retightened with a power wrench to 35,000 to 40,000 lb tension. The wrench cut-off was set by the use of a bolt tension extensometer. Compression clips were used as anchors, and were applied immediately after the joints had been tightened. In general, the tight rail test installation was built in accordance with several basic suggestions for continuous welded rail made by the Special Committee on Continuous

Welded Rail, as published in Vol. 54, 1953, page 1162–1169. After laying the rail, the track was smoothed or spot surfaced with a power tamper. Additional slag ballast was then applied to increase the shoulder width to about 10 in more than normal. Most of the test stretch has 2 tie plate lock spikes for hold-down fastenings. The track is laid on creosoted hardwood ties and had excellent line and surface when inspected in September 1955. End zone anchorage was provided at each end of the tight rail by boxing every tie, except joint ties, with conventional rail base anchors in eight panels of track.

The section of tight rail was anchored with compression clips in three ways: the north 94 rails of the test section with clips on the field end of the plates on all ties except joint and shoulder ties; the next 66 rails with clips on the field side of each rail on alternate ties, except the joint ties; and the south 74 rails with clips on the gage side of each rail on alternate ties, except joint ties. Signal bonds were used in the tight rail section, as in the normal rail.

The rail used was not end hardened or chamfered. The rail ends were specified to be cut square. Because it was the practice of the steel mill to end mill all rails, these rails were also end milled. It is not known whether the rail base was undercut in the end milling process. However, when the rail was laid tight, all of the joint gaps were closed, indicating that the rail base did not foul and keep the rail heads from abutting properly. No lubrication was used on the joints. In assembling the north 40 joints an attempt was made to remove the quenching oil from the joint bars, but with little success. No abrasive was used on these joints. For increasing the slippage resistance of the next 100 joints, thin coats of shellac and powdered aluminum oxide were applied to the contact surfaces of the joint bars. The remainder of the joint bars were placed without surface treatment.

No maintenance work has been performed on the tight rail test. The bolts were not retightened until October 1955, when the AAR research staff was taking the initial test readings. At that time, by use of a bolt tension extensometer, the power wrench was set to apply 40,000 to 45,000-lb bolt tension.

The AAR test was laid out to exclude 6 track panels of tight rail on each end, leaving 105 panels or 211 joints. These joints were numbered from 300 to 510, incl.

Description of Normal Rail Test Section

The location selected was to the south of the tight rail. This test extends from a point 8½ panels south of the south end zone anchorage to about 3 rails north of MP 226. The joints are numbered from 1 to 210, incl. This rail was end hardened and chamfered, and was laid with the same material and in the same year, except for rail anchorage and hold-down fastenings. The section was laid with normal bolt tension and the bolts were retightened in October 1955 to from 15,000 to 25,000 lb. The track is anchored with rail base anchors boxed on 4 alternate ties in each one-half panel of track —the same as the AREA recommended minimum anchorage for tracks carrying two-way traffic. No special hold-down fastenings were used.

It was not possible to select comparable grades of the track in the two sections. The tight rail has over one-half of its length on level grade and the balance on a 0.40 percent grade ascending northward, whereas, the normal rail section is entirely on a 0.40 percent grade ascending northward. The major portion of each test stretch is on embankment ranging from zero to approximately 12 ft high. At subgrade level, the embankment is narrower in the normal rail test section, which has the L&N standard ballast shoulder, while the tight rail has shoulders about 10 in wider.

Fig. 1—General northward view of tight rail test section, L&N Mile 225.

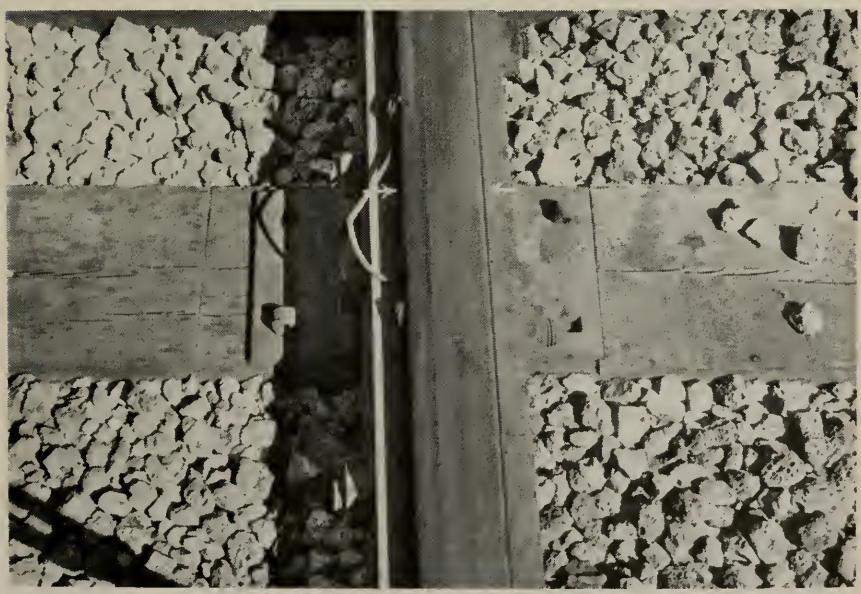


Fig. 2—Typical joint in the tight rail in good condition.

Test Measurements

The AAR research staff took initial or base readings on 20 joints (10 in each rail) in each section as follows: Rail surface profile, and out-to-out readings on the joints for determining the pull-in or joint wear. All rail joint gaps were measured in October 1955, and steel bars were set to measure cumulative rail creepage at ¼-points in the tight rail section and at ⅓-points in the normal rail. Rail gaps and creepage will be checked each summer and winter. Ten of the above 20 joints in the tight rail section were used to set up a bolt tension test with approximately 45,000 lb tension. From these data, the frequency of retightening of the bolts will be determined. In the normal rail, it is planned to have the bolts retightened each autumn.

Acknowledgement

The Association is indebted to the L&N for its cooperation in providing the test trackage and assistance in the conduct of the service test.

Report on Assignment 9

Critical Review of the Subject of Speed on Curves and Turnouts as Affected by Present-Day Equipment

W. R. Bjorklund (chairman, subcommittee), L. L. Adams, W. E. Cornell, H. W. Cox, Jr., E. R. Murphy, Troy West.

This report embraces material for adoption and publication in the Manual as a substitute for the material now appearing therein on pages 5–3–9 to 5–3–12, incl., beginning with "Elevations and Speeds for Curves", and including "Speeds of Trains Through Level Turnouts."

ELEVATIONS AND SPEEDS ON CURVES

1. Elevation of Curves

The approximate formula: $e = \frac{Bv^2}{32.16\,R}$

in which e = Equilibrium elevation in feet,
B = Bearing distance of track level on rails in feet,
v = Velocity in feet per second,
R = Radius of curve in feet,

will give, for small angles where the sine and the tangent are approximately equal, essentially correct theoretical equilibrium elevation for the outer rail of curves.

From the foregoing may be derived the simplified formula,

$$E = 0.0007\ V^2D$$

in which E = Equilibrium elevation in inches of the outer rail (center to center of rails, or 4 ft 11½ in),

D = Degree of curve,
V = Speed in miles per hour

Equilibrium speed on a curve is the speed at which the resultant of the weight and the centrifugal force is perpendicular to the plane of the track. Therefore, the components of the centrifugal force and the weight in the plane of the track are balanced. If it were possible to operate all classes of traffic at the same speed on a curve, the ideal condition for smooth riding and minimum rail wear would be obtained by elevating for equilibrium. However, curved track must handle several classes of traffic operating at various speeds, which results in slow trains causing excessive wear on the inside rail and high-speed trains causing accelerated wear on the outside rail.

The car body assumes a different position when the speed of the car is greater than the equilibrium speed. In this case, the elevation will not be completely effective in balancing out the centrifugal force created by the circular motion of the car. With this unbalanced force acting at the center of gravity of the car body, the body will be displaced outwardly and will tilt on the springs and swing hangers toward the outside of the curve. Under normal conditions, when the car is above the equilibrium speed, the car body will not incline from the vertical at an angle as great as the track angle. The difference between the track angle and the car angle is called the roll angle. The less the roll angle, the better comfort obtained in going around curves.

Safety and comfort limit the speed with which a passenger train may negotiate a curve. Any speed which gives comfortable riding on a curve is well within the limits of safety. Experience has shown that the conventional baggage cars, passenger coaches, diners, and Pullman cars will ride comfortably around a curve at a speed which will require an elevation about 3 in higher for equilibrium. Equipment designed with large center bearings, roll stabilizers, and outboard swing hangers can negotiate curves comfortably at greater than 3 in unbalanced elevation because there is less car body roll. It is suggested that where complete passenger trains are equipped with cars utilizing the foregoing refinements that a lean test be made on the equipment to determine the amount of body roll. Lean tests may be made on tangent track by running one side of the car onto oak shims, using winches to move the car on and off the shims. Cars should be elevated to three heights: usually 2 in, 4 in, and 6 in. If the roll angle is less than 1° 30′, experiments indicate that cars can negotiate curves comfortably at 4½ in unbalanced elevation.

The inner rail should preferably be maintained at grade.

Table 1 gives the equilibrium elevation of various degrees of curvature for speed in miles per hour in multiples of five (which is the general practice used on speed limit signs).

E = Equilibrium Elevation For Various Speeds On Curves

D=Degree of Curve	V = Speed in Miles per Hour																
	10	20	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0° 30′	0.04	0.14	0.32	0.43	0.56	0.71	0.88	1.06	1.26	1.48	1.72	1.97	2.24	2.53	2.84	3.16	3.50
1° 00′	0.07	0.28	0.63	0.87	1.12	1.42	1.75	2.12	2.52	2.96	3.43	3.94	4.48	5.06	5.67	6.32	7.00
1° 30′	0.11	0.42	0.95	1.29	1.68	2.13	2.63	3.18	3.78	4.44	5.15	5.91	6.72	7.59	8.51	9.48	10.50
2° 00′	0.14	0.56	1.26	1.72	2.24	2.84	3.50	4.24	5.04	5.92	6.86	7.88	8.96	10.12	11.34	12.64	
2° 30′	0.18	0.70	1.58	2.14	2.80	3.54	4.38	5.29	6.30	7.39	8.58	9.84	11.20				
3° 00′	0.21	0.84	1.89	2.57	3.36	4.25	5.25	6.35	7.56	8.87	10.29	11.81					
3° 30′	0.25	0.98	2.21	3.00	3.92	4.96	6.13	7.41	8.82	10.35							
4° 00′	0.28	1.12	2.52	3.43	4.48	5.67	7.00	8.47	10.08								
5° 00′	0.35	1.40	3.15	4.29	5.60	7.09	8.75	10.59									
6° 00′	0.42	1.68	3.78	5.15	6.72	8.51	10.50										
7° 00′	0.49	1.96	4.41	6.00	7.84	9.92											
8° 00′	0.56	2.24	5.04	6.86	8.96	11.34											
9° 00′	0.63	2.52	5.67	7.72	10.08												
10° 00′	0.70	2.80	6.30	8.58	11.20												
11° 00′	0.77	3.08	6.93	9.43													
12° 00′	0.84	3.36	7.56	10.29													

"E" in Inches = $0.0007V^2D$

Table 1

SPEEDS OF TRAINS THROUGH LEVEL TURNOUTS

The following tables show speeds through level turnouts giving riding conditions equivalent to those obtained in traversing a curve elevated 3 in less than that required for equilibrium.

Speeds through turnouts with either straight or curved switch points are calculated from the equation $E = 0.0007\ V^2D - 3$ (see Elevations and Speeds for Curves, Part 3, this Chapter), where D equals the degree of curvature of the closure curve or the switch curve, whichever is sharper; for turnouts with straight switch points, D for the switch point curve is the degree of curvature of a curve having a central angle equal to the switch angle and a chord length equal to length of the switch points.

TURNOUTS WITH STRAIGHT SWITCH POINTS (AREA)

Turnout Number	*Length of Switch Points*	*Speed in Miles Per Hour*	
		Lateral Turnouts	*Equilateral Turnouts*
5	11′–0″	12	16
6	11′–0″	13	19
7	16′–6″	17	23
8	16′–6″	19	27
9	16′–6″	20	28
10	16′–6″	20	28
11	22′–0″	26	37
12	22′–0″	27	38
14	22′–0″	27	38
15	30′–0″	36	51
16	30′–0″	36	52
18	30′–0″	36	52
20	30′–0″	36	52

TURNOUTS WITH CURVED SWITCH POINTS (AREA)

Turnout Number	*Length of Switch Points*	*Speed in Miles Per Hour*	
		Lateral Turnouts	*Equilateral Turnouts*
5	13′–0″	12	17
6	13′–0″	15	21
7	13′–0″	18	25
8	13′–0″	20	28
9	19′–6″	22	30
10	19′–6″	25	35
11	19′–6″	28	39
12	19′–6″	29	40
14	26′–0″	34	49
15	26′–0″	38	53
16	26′–0″	40	57
18	39′–0″	44	63
20	39′–0″	50	70

For passenger trains completely equipped with cars in which the lean tests show a roll angle of less than 1° 30′, trains may operate comfortably through turnouts at 12 percent higher speeds than those indicated in the foregoing.

Report on Assignment 10

Methods of Heat Treatment, Including Flame Hardening, of Bolted Rail Frogs and Split Switches, Together with Methods of Repair by Welding

S. H. Poore (chairman, subcommittee), L. L. Adams, M. C. Bitner, J. C. Brennan, T. F. Burris, W. E. Cornell, F. W. Creedle, L. E. Donovan, W. E. Griffiths, V. C. Hanna, D. C. Hastings, A. E. Haywood, C. C. Herrick, L. H. Jentoft, C. H. Johnson, T. R. Klingel, H. B. Orr, C. E. Peterson, W. A. Schubert, R. D. Simpson, T. R. Snodgrass, R. E. Tew, K. H. Von Kampen, D. J. White.

Tests of Welding Techniques for Repair and Serviceability of Four Metallurgies of Rail Steel in Simulated Units of Bolted Rail Crossing Flangeway Intersections

This is a progress report on the service tests of the simulated crossing flangeway intersections in bolted rail construction, and is offered as information.

Introduction

Last year's report of the committee (Vol. 56, 1955, page 878), included a description of the installation on the Chicago, Milwaukee, St. Paul & Pacific, at Mannheim, Ill., of three 39-ft panels, each consisting of 8 units of simulated crossing intersections in bolted rail construction, as shown in Fig. 1. The installation was made in the westward freight main No. 3 and completed April 1954. It will be observed from the figure that each test panel includes flame-hardened units by three manufacturers, heat-treated units by another three frog and switch manufacturers, and one unit each of control-cooled rail, as rolled, and used chrome-vanadium rail. Field measurements of the rail wear and batter and Brinell hardness were taken in July 1955, after the test panels had carried approximately 27 million gross tons of traffic.

In connection with determining the proper welding procedures to be used in the maintenance of the units of 4 metallurgies, 30 laboratory test welds were made in February 1955 on 8 rails having identical treatment as in the field units. There were 16 electric and 14 gas welds made with the cooperation of three nationally known welding companies, 2 of the suppliers of the test units, and 2 Member Roads. A metallurgical examination has been completed on the 30 specimen welds, and selection of the better welding procedures will be made by the AAR research staff this winter. A report on this phase of the investigation will be made in the winter of 1956.

Maintenance of Tread Corners

By April 1955 the metal flow in the flangeways of the control-cooled rail units had progressed to such an extent that it was necessary the grind off the flow to avoid chipping. The maximum flow was caused by the false flanges of the wheels (tread worn hollow) on the receiving corner of the easer rails. A thorough grinding of the metal flow from the flangeways of the unhardened units was done. While doing this grinding a small amount of work was done on all of the other flangeways.

Rail Wear and Batter, and Brinell Hardness

These measurements were made on the running rails with the special equipment described in last year's report. These data have been summarized in Table 1 in four parts. The hardness readings include the hardness of the top of the running rails prior

(Text continued on page 774)

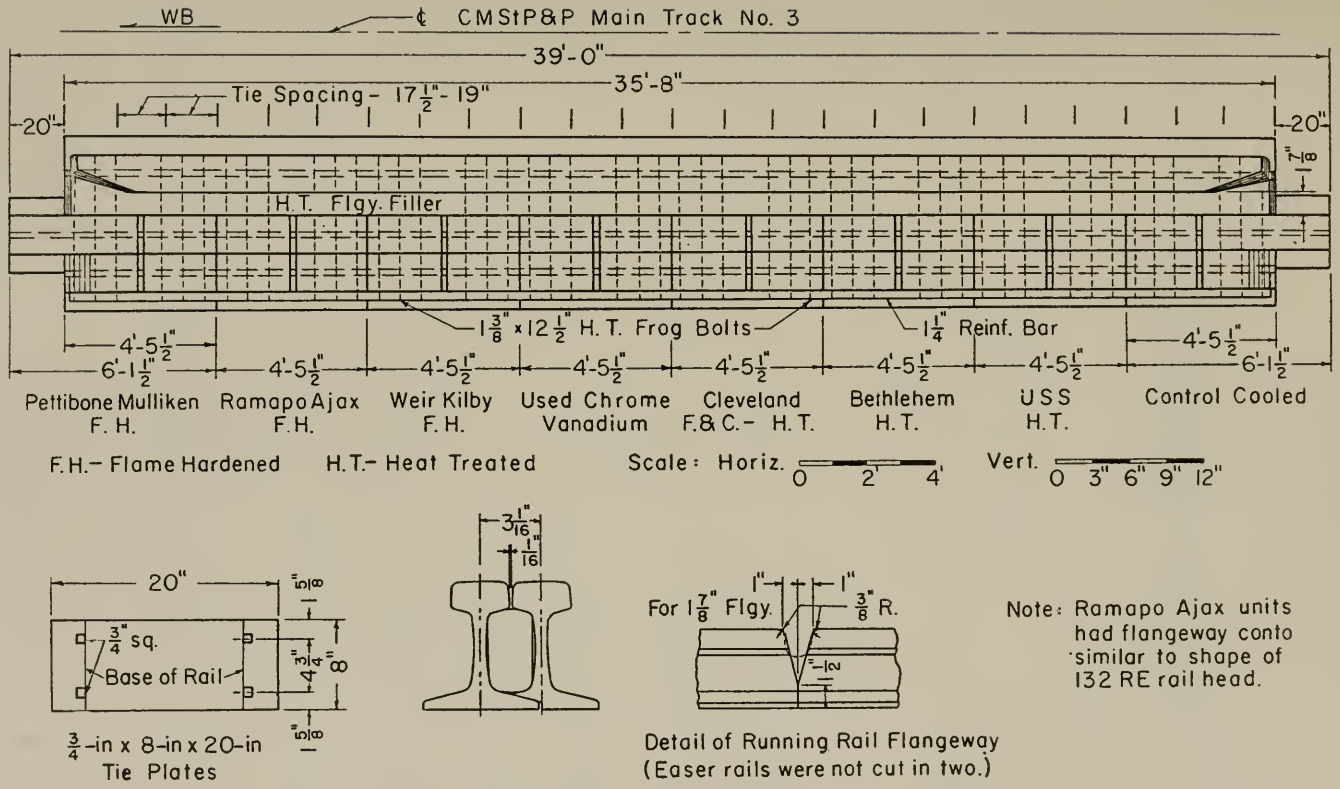


Fig. 1. Plan of One Panel of Eight Units of Simulated 132 RE Bolted Rail Crossing Flangeway Intersections at Mannheim, Illinois.

TABLE 1, PART 1. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS.

WEST PANEL Test period, April 13, 1954 to July 15, 1955

Designation of Unit	Location	Rail Head Wear and Batter			Brinell Hardness (3000 kg)			
							Increase	
		Avg Normal Wear in	Wear Plus Batter in	Batter Only in	Initial	7-15-55	Normal	F. W. Cor.
Flame Hardened Rail								
Pettibone	Avg. Both Ends	0.012			312	348	36	
Mulliken	Rec. Cor.		0.066	0.054	307	361		54
Corporation	Lv. Cor.		0.024	0.012	309	364		55
Ramapo Ajax Div.	Avg Both Ends	0.010			360	384	24	
American Brake	Rec. Cor.		0.056	0.046	359	385		26
Shoe Company	Lv. Cor.		0.024	0.014	351	385		34
Weir Kilby	Avg Both Ends	0.010			328	362	34	
Corporation	Rec. Cor.		0.076	0.066	302	361		59
	Lv. Cor.		0.022	0.012	321	354		33
Heat Treated Rail								
Cleveland Frog	Avg Both Ends	0.006			339	360	21	
and Crossing	Rec. Cor.		0.033	0.027	340	385		45
Company	Lv. Cor.		0.012	0.006	344	375		31
Bethlehem Steel	Avg Both Ends	0.005			340	359	19	
Company	Rec. Cor.		0.035	0.030	327	390		63
	Lv. Cor.		0.012	0.007	337	373		36
United States	Avg Both Ends	0.008			310	352	42	
Steel Corporation	Rec. Cor.		0.035	0.027	344	393		49
	Lv. Cor.		0.015	0.007	347	390		43
Other Rails								
Used Chrome-	Avg Both Ends	0.007			366	381	15	
Vanadium Rail	Rec. Cor.		0.031	0.024	366	373		7
	Lv. Cor.		0.013	0.006	366	371		5
C. C. Blue End	Avg Both Ends	0.014			256	288	32	
Rail as rolled	Rec. Cor.		0.096	0.082	249	300		51
	Lv. Cor.		0.030	0.016	242	295		53

TABLE 1, PART 2. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS.

CENTER PANEL Test Period, April 13, 1954 to July 15, 1955

Designation of Unit	Location	Rail Head Wear and Batter			Brinell Hardness (3000 kg)			
							Increase	
		Avg Normal Wear in	Wear Plus Batter in	Batter Only in	Initial	7-15-55	Normal	F. W. Cor.
Flame Hardened Rail								
Pettibone	Avg Both Ends	0.011			312	346	34	
Mulliken	Rec. Cor.		0.067	0.056	315	361		46
Corporation	Lv. Cor.		0.025	0.014	324	371		47
Ramapo Ajax Div.	Avg Both Ends	0.009			338	372	34	
American Brake	Rec. Cor.		0.052	0.043	368	396		28
Shoe Company	Lv. Cor.		0.022	0.013	351	390		39
Weir Kilby	Avg Both Ends	0.010			321	364	43	
Corporation	Rec. Cor.		0.072	0.062	321	359		38
	Lv. Cor.		0.022	0.012	324	368		44
Heat Treated Rail								
Cleveland Frog	Avg Both Ends	0.007			336	364	28	
and Crossing	Rec. Cor.		0.033	0.026	332	377		45
Company	Lv. Cor.		0.013	0.006	329	366		37
Bethlehem Steel	Avg Both Ends	0.005			337	372	35	
Company	Rec. Cor.		0.037	0.032	340	393		53
	Lv. Cor.		0.011	0.006	340	387		47
United States	Avg Both Ends	0.008			338	370	32	
Steel Corporation	Rec. Cor.		0.036	0.028	323	390		67
	Lv. Cor.		0.015	0.007	342	387		45
Other Rails								
Used Chrome-	Avg Both Ends	0.007			362	378	16	
Vanadium Rail	Rec. Cor.		0.031	0.024	359	364		5
	Lv. Cor.		0.013	0.006	361	385		24
C. C. Blue End	Avg Both Ends	0.014			252	292	40	
Rail as rolled	Rec. Cor.		0.095	0.081	254	302		48
	Lv. Cor.		0.035	0.021	255	304		49

A

TABLE I, PART 3. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SUMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS.

EAST PANEL Test Period, April 13, 1954 to July 15, 1955

Designation of Unit	Location	Rail Head Wear and Batter			Brinell Hardness (3000 kg)			
							Increase	
		Avg Normal Wear in	Wear Plus Batter in	Batter Only in	Initial	7-15-55	Normal	F. W. Cor.
Flame Hardened Rail								
Pettibone	Avg Both Ends	0.011			296	340	44	
Mulliken	Rec. Cor.		0.066	0.055	311	373		62
Corporation	Lv. Cor.		0.024	0.013	302	364		62
Ramapo Ajax Div.	Avg Both Ends	0.009			344	386	42	
American Brake	Rec. Cor.		0.051	0.042	366	412		46
Shoe Company	Lv. Cor.		0.020	0.011	364	405		41
Weir Kilby	Avg Both Ends	0.010			303	358	55	
Corporation	Rec. Cor.		0.073	0.063	290	373		83
	Lv. Cor.		0.022	0.012	309	368		59
Heat Treated Rail								
Cleveland Frog	Avg Both Ends	0.006			329	370	41	
and Crossing	Rec. Cor.		0.035	0.029	337	393		56
Company	Lv. Cor.		0.013	0.007	334	373		39
Bethlehem Steel	Avg Both Ends	0.006			353	381	28	
Company	Rec. Cor.		0.041	0.035	342	385		43
	Lv. Cor.		0.013	0.007	324	371		47
United States	Avg Both Ends	0.008			304	336	32	
Steel Corporation	Rec. Cor.		0.039	0.031	311	377		66
	Lv. Cor.		0.017	0.009	332	371		39
Other Rails								
Used Chrome-	Avg Both Ends	0.006			361	390	29	
Vanadium Rail	Rec. Cor.		0.033	0.027	366	390		24
	Lv. Cor.		0.014	0.008	366	371		5
C. C. Blue End	Avg Both Ends	0.015			246	294	48	
Rail as rolled	Rec. Cor.		0.098	0.083	245	307		62
	Lv. Cor.		0.033	0.018	255	307		52

TABLE 1 , PART 4. SUMMARY OF RAIL HEIGHT MEASUREMENTS AND BRINELL HARDNESS READINGS TAKEN ON THE THREE SIMULATED CROSSING INTERSECTION PANELS IN THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS.

AVG. OF PANELS Test Period, April 13, 1954 to July 15, 1955

Designation Of Unit	Location	Rail Head Wear and Batter			Brinell Hardness (3000 kg)			
							Increase	
		Avg Normal Wear in	Wear Plus Batter in	Batter Only in	Initial	7-15-55	Normal	F. W. Cor.
Flame Hardened Rail								
Pettibone	Avg Both Ends	0.011			307	345	38	
Mulliken	Rec. Cor.		0.066	0.055	311	365		54
Corporation	Lv. Cor.		0.024	0.013	312	366		54
Ramapo Ajax Div.	Avg Both Ends	0.009			347	381	34	
American Brake	Rec. Cor.		0.053	0.044	364	398		34
Shoe Company	Lv. Cor.		0.022	0.013	355	393		38
Weir Kilby	Avg Both Ends	0.010			317	361	44	
Corporation	Rec. Cor.		0.074	0.064	304	364		60
	Lv. Cor.		0.022	0.012	318	363		45
Heat Treated Rail								
Cleveland Frog	Avg Both Ends	0.006			335	365	30	
and Crossing	Rec. Cor.		0.034	0.028	336	385		49
Company	Lv. Cor.		0.013	0.006	336	371		35
Bethlehem Steel	Avg Both Ends	0.005			343	371	28	
Company	Rec. Cor.		0.038	0.033	336	389		53
	Lv. Cor.		0.012	0.007	334	377		43
United States	Avg Both Ends	0.008			317	353	36	
Steel Corporation	Rec. Cor.		0.037	0.029	326	387		61
	Lv. Cor.		0.016	0.008	340	383		43
Other Rails								
Used Chrome-	Avg Both Ends	0.007			363	383	20	
Vanadium Rail	Rec. Cor.		0.032	0.025	364	376		12
	Lv. Cor.		0.013	0.007	364	376		12
C. C. Blue End	Avg Both Ends	0.014			251	291	40	
Rail as rolled	Rec. Cor.		0.096	0.082	249	303		54
	Lv. Cor.		0.033	0.018	251	302		51

Notes: All rail height measurements and Brinell readings were taken on the longitudinal center line of the running rail. The data taken 10 in. from both ends of each unit were used for determining the normal head wear and work hardening of the running rail. Rail head wear and work hardening of the tread corners were based on the readings taken 3/4 in. from the adjacent side of each flangeway. The total gross tons of traffic for the test period was approximately 27 million.

to installing the panels and after 27 million gross tons of traffic, and also the increase in hardness due to work hardening. Part 4 of the table includes the averages for each of the groups of three similar test units. There were some variations in the values of batter and hardness increase in the groups of three manufacturer's flame-hardened and heat-treated units. No significance should be given to these differences because of the short test period and small traffic tonnage.

It will be of interest to compare the relative amounts of rail batter on the receiving corners of the four general groups of metallurgy.

Category	*Batter Inches*	*Relative Percent*
OHCC rail units	0.082	100
All flame-hardened units	0.054	66
All heat-treated units	0.030	37
Used C–V rail	0.025	31

Generally, the rail batter for the flame-hardened units was two-thirds as much as for normal rail, and for the heat-treated and used C–V units was one-third as much.

All of the rail categories were work hardened to some extent, but this was a minimum for the C–V units. It was indicated in the last report from the laboratory test of Tukon Micro-Hardness measurements on a slice of the used C–V rail, that the maximum hardness was from 0.6 to 0.8 mm below the top of rail. The top of the rail had a BHN of 361, compared to 382 at the above depths.

It is anticipated that it will be necessary to build up the tread corners of the OHCC units in 1956.

Acknowledgement

In the conduct of this assignment the splendid assistance and cooperation on the part of the Milwaukee Road and the suppliers of the test units are gratefully acknowledged. The Association also extends its deep appreciation to the following companies for their valuable assistance and counsel in conducting the welding experiments.

Milwaukee Road (Electric Welding),
Burlington Road (Gas Welding),
Air Reduction Sales Company,
Linde Air Products Company (Oxweld),
Teleweld, Incorporated,
Bethlehem Steel Company,
American Brake Shoe Company, Ramapo Ajax Division.

Report of Special Committee on Continuous Welded Rail

C. E. Weller, *Chairman,*
J. C. DeJarnette, Jr.
Vice Chairman,
R. E. Dove, *Secretary,*

H. C. Archibald*
S. H. Barlow
T. A. Blair
Blair Blowers
C. B. Bronson
E. J. Brown
H. B. Christianson
W. E. Cornell
L. S. Crane
F. W. Creedle
A. G. Ellefson
P. O. Ferris
H. F. Fifield
W. H. Freeman
R. J. Gammie
J. W. Hopkins**
S. R. Hursh
T. B. Hutcheson
A. B. Lewis
C. P. Martini
C. R. Merriman
Wm. Nuetzel
J. L. Parker, Jr.
W. C. Perkins
L. F. Racine
J. M. Rankin
F. L. Rees
E. F. Salisbury
T. C. Shedd, Jr.
H. A. Siravo
R. P. Winton
Edward Wise, Jr.
Committee

* Died August 6, 1955.
** Died April 5, 1955.

To the American Railway Engineering Association:

Your Committee reports on the following subjects:

1. Fabrication.

   Progress report, presented as information ..... page 776

2. Laying.

   No report.

3. Fastenings.

   No report.

4. Maintenance.

   No report.

5. Economics.

   Progress in study, but no report.

The Special Committee on Continuous Welded Rail,
C. E. Weller, *Chairman.*

AREA Bulletin 528, February 1956.

Report on Assignment 1

Fabrication

W. Nuetzel (chairman, subcommittee), C. E. Weller, J. C. DeJarnette, Jr., S. H. Barlow, L. S. Crane, F. W. Creedle, H. F. Fifield, R. P. Winton.

This is the fourth progress report on this subject and is submitted as additional information.

The three previous reports have dealt primarily with the oxyacetylene process, references having been made, however, to the advent of the electric flash butt weld process.

This report deals mainly with the electric flash butt welding of rails as performed on the Atchison, Topeka & Santa Fe. The equipment used has been assembled in three standard railroad cars, which include a welding car, housing the welding equipment; a diesel generator car, which supplies the welding current; and a grinder car. The welding car and grinder car are placed end to end on one track, while the generator car is located directly opposite the welding car on an adjacent track.

In the electric flash butt rail welding, the rails do not have to be sawed, but are merely cleaned on the rail end face and on the adjacent electrode-contact surfaces on the head and base to remove any mill scale and dirt. This cleaning is done by one man with a power sanding machine.

Upon completion of the cleaning operation, the rail is moved on pedestal rollers into the welding machine, which is a flash welder of fully automatic type, combining hydraulic and pneumatic operation. It is especially designed for the flash welding of railroad rails, being capable of accommodating mild and carbon steel rails with a maximum cross section of 15.5 sq in.

The first rail to be welded rolls through the welding car until its rear end is approximately centered in the welder. The next rail is then fed into place. If the ends are not exactly centered in the welder, the operation of a hydraulic press valve will move the welder until the joint is exactly centered, after which the rails are alined and clamped both vertically and horizontally.

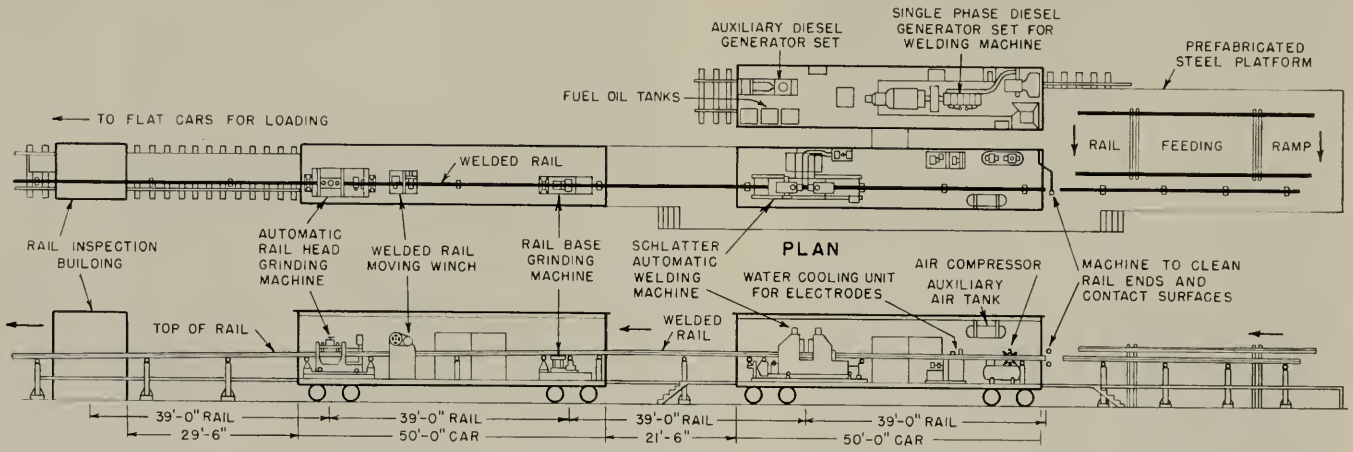
Upon the completion of these preliminaries, the actual welding is carried out in the five following steps.

1—Pre-heating
2—Flashing
3—Upsetting
4—Current interruption
5—Burr removing.

In pre-heating, the rail ends are heated to approximately 2000 deg F by turning on the welding current and bringing together the abutting surfaces for a few seconds, then separating them, and then bringing them into contact again. This is repeated until the proper pre-heating temperature is reached.

The flashing operation, which is controlled by a hydraulic brake unit pushing the movable second rail toward the stationary first rail, starts when the rail ends touch. The contacting parts of the rail are heated immediately by a high current and the material immediately at the ends is ejected in a liquid state out of the welding zone, leaving the weld free from slag and scale. The welding joint is then heated uniformly to welding temperature.

(Text continued on page 781)



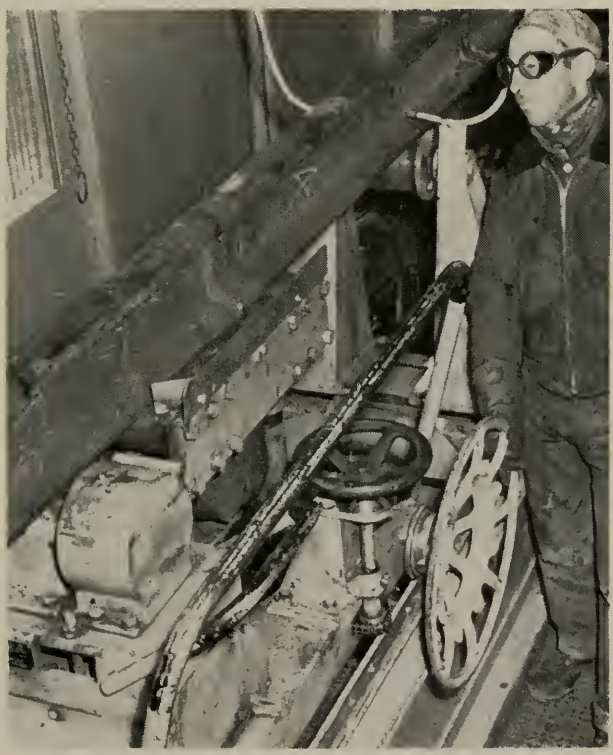
LONGITUDINAL SECTION

LAYOUT OF ELECTRIC FLASH BUTT-WELDING

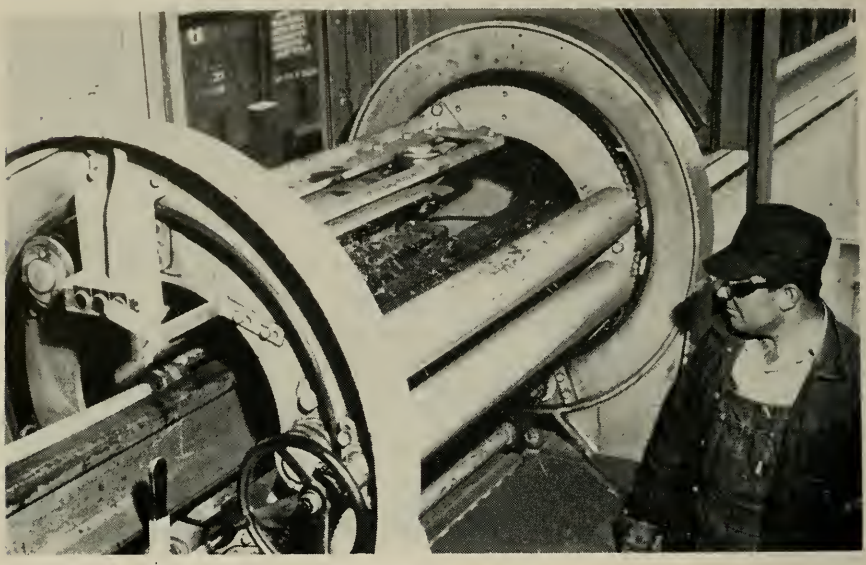
Lengths of rail on rack ready to be fed into the first car, which contains the welding machine, of the electric flash butt welding set-up on the Santa Fe.

After the rail ends have been lined up, the operator closes the flash guard of the machine and starts the weld. The welding car contains, in addition to the welding machine, an air compressor and reservoir, water cooling unit to cool electrodes and hydraulic fluid, and a portable grinder for cleaning rail ends and electrode contact surfaces.

Above — After welding, the upset metal on base and head of rail is sheared off with cutting blades activated by hydraulic pressure.



Right—The rail is then moved into the second car where the rail base is ground by the machine shown here.



Above—After the base grinding operation, the rail moves to this machine where the rail head contour is ground. In addition to the grinding machines, the grinding car contains a winch for moving the rail, a monorail, a hoist for the rail clamp, and a portable rail saw.

Left—The rail is next moved into a prefabricated steel shed where the soundness of each weld is tested by Magnaflux.

The upsetting begins instantaneously after sufficient material has been flashed off and the rail ends have reached welding temperature. This upsetting occurs as the result of an oil brake, which has been in operation up to this point, being suddenly released,, allowing the full force of an hydraulic press to push one rail against the other with sufficient force to cause the molten metal into an upset.

The current interruption is automatically set at a few tenths of a second according to requirements.

Most of the burr on the bottom and edges of the base and on the top and sides of the head, caused by upsetting, is removed while it is still hot. This is done in the welding machine itself by means of a burr-removing shear.

Upon completion of a weld, the rail is pulled forward for the next weld by means of a winch located on the grinder car, but controlled by the welder operator. This brings the completed weld to the first of two grinding stations in the grinder car where two grinding machines are used to remove all the remaining upset metal on the bottom and edges of the base of rail. While this grinding is taking place, another grinder at the far end of the car is at work at the joint immediately in advance, trimming up the head. Each grinding operation is handled by one man.

While this grinding is under way, the joint weld immediately ahead of the second grinding station is inspected magnetically for any defects.

As the rails leave the inspection station, they move out onto a string of flat cars, specially equipped with rollers to receive them. Normally, thirty-seven 39-ft rails are welded into continuous strings and 12 of these long rails are loaded on the cars for movement to the site of unloading and laying.

Report of Committee 4—Rail

B. R. Meyers, *Chairman,*

L. S. Crane,
Vice Chairman,
A. P. Talbot, *Secretary,*
W. D. Almy
E. L. Anderson
S. H. Barlow

F. W. Biltz
T. A. Blair
Blair Blowers
B. Bristow
C. B. Bronson
R. M. Brown
E. E. Chapman (E)
B. Chappell
C. J .Code
W. J. Cruse
J. C. DeJarnette
G. H. Echols
P. O. Ferris
E. B. Fields
J. K. Gloster
J. L. Gressitt
R. L. Groover
W. H. Hobbs
S. R. Hursh
J. C. Jacobs
K. K. Kessler
N. W. Kopp
L. R. Lamport
C. C. Lathey
W. B. Leaf

H. S. Loeffler
Ray McBrian
E. H. McGovern
L. T. Nuckols
Embert Osland
E. E. Oviatt
R. E. Patterson
W. H. Penfield (E)
W. C. Perkins
G. L. P. Plow
W. G. Powrie
R. B. Rhode
C. R. Riley
J. G. Roney
E. F. Salisbury
J. F. Shaffer
S. H. Shepley
A. A. Shillander
W. D. Simpson
G. L. Smith
J. S. Wearn
H. F. Whitmore
R. P. Winton
Edw. Wise, Jr.
J. E. Yewell

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommendation for minor changes and adoption of 140-lb headfree joint bar ..... page 784

2. Collaborate with AISI Technical Committee on Rail and Joint Bars in research and other matters of mutual interest.

   Progress report, including as Appendix 2–a Report on Investigation of Failures in Control-Cooled Rails ..... page 787

3. Rail failure statistics covering (a) all failures; (b) transverse fissures; (c) performance of control-cooled rail.

   Progress report, including statistics on rail failures reported up to December 31, 1954 ..... page 794

4. Rail end batter; causes and remedies.

   Brief progress report, presented as information ..... page 814

5. Economic value of various sizes of rail.

   Progress report, presented as information ..... page 815

6. Service tests of various types of joint bars.

   Brief progress report, presented as information ..... page 817

7. Joint bar wear and failures; revision of design and specification for new bars, including insulated joints, and bars for maintenance repairs.
Progress report, presented as information ..... page 817
Appendix 7–a—Fourteenth progress report on the Rolling-Load Tests of Joint Bars ..... page 818

8. Causes of shelly spots and head checks in rail; methods for their prevention.
Progress report, including report on service tests on heat-treated and alloy steel rails, presented as information ..... page 830
Appendix 8–a—Fourteenth progress report on Shelly Rail Studies at the University of Illinois ..... page 850

9. Recent developments, affecting rail section.
Progress report, presented as information, including comments on velocity power punch ..... page 858

10. Service performance and economics of 78-ft rail; specifications for 78-ft rail.
Progress report, presented as information ..... page 859
Appendix 10-a—Joint gap measurements ..... page 860
Appendix 10-b—Tests of rail joint impact effect ..... page 865

11. Rail damage resulting from engine burns, prevalence; means of prevention; repair by welding.
Progress report, presented as information ..... page 883

THE COMMITTEE ON RAIL,
B. R. MEYERS, *Chairman.*

AREA Bulletin 528, February 1956.

Report on Assignment 1

Revision of Manual

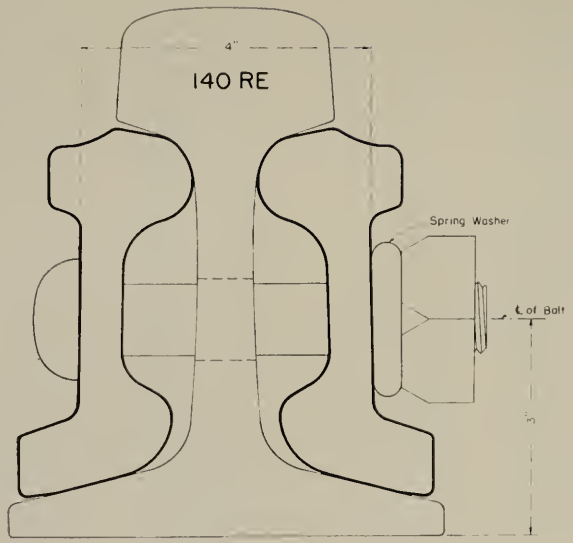
L. S. Crane (chairman, subcommittee), E. L. Anderson, F. W. Biltz, J. L. Gressitt, R. L. Groover, W. H. Hobbs, C. C. Lathey, H. S. Loeffler, Ray McBrian, B. R. Meyers, L. T. Nuckols, E. E. Oviatt, R. E. Patterson, G. L. P. Plow, R. B. Rhode, E. F. Salisbury, S. H. Shepley, A. A. Shillander, G. L. Smith, J. S. Wearn, H. F. Whitmore, Edward Wise, Jr.

The following revisions are submitted with the recommendation that they be adopted and published in the Manual:

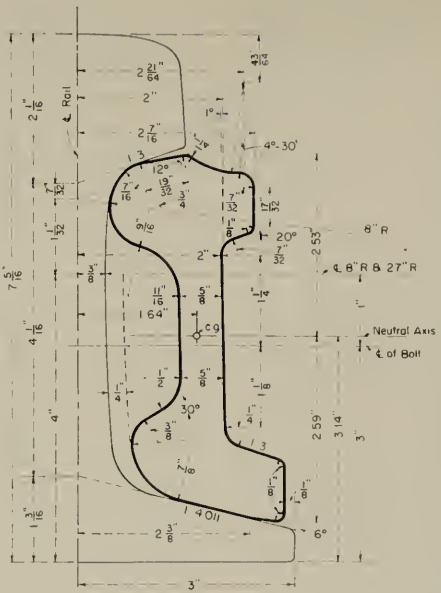
Pages 4–1–6.2 to 4–1–12.1, incl.

JOINT BARS AND ASSEMBLIES

Adopt as an AREA recommended section the 140-lb headfree joint bar shown in accompanying Fig. 7b. Bolt hole punching is to conform to rail drilling 3 in above base of rail, as described for the 140 RE rail. Include in Manual as part of "Joint Bars and Assemblies".



ASSEMBLY



SECTION

Fig. 7b—Headfree joint bar and assembly for 140 RE rail.

Physical Properties	*One Bar*	*Two Bars*
Moment of Inertia in^4	15.94	31.9
Section Modulus (Above n. a. in^3)	6.30	12.6
Section Modulus (Below n. a. in^3)	6.15	12.3
Area sq in	5.98	11.96
Net weight, 24-in length, lb	39.9	79.8
Net weight, 36-in length, lb	59.9	119.7

Pages 4–2–1 to
4–2–6, incl.

SPECIFICATIONS FOR OPEN-HEARTH STEEL RAILS

Reapprove this specification with the following revisions:

On page 4–2–6 of this specification, revise the wording of Art. 17 (e), to read as follows:

"All rails of a heat in which both the carbon and manganese content are above the mean of the specified range shall have both ends painted blue."

On page 4–2–6 of this specification, revise the wording of Art. 18 (a) and 18 (b) to read as follows:

(a) "No. 1 rails with carbon and/or manganese content below the mean of the specified range shall be loaded in separate cars."

(b) "No. 1 rails with carbon and manganese content above the mean of the specified range shall be loaded in separate cars."

Pages 4–3–10 and
4–3–11

RAIL RECORD FORMS

Form 402–C (a)—Instructions for Filling in Rail Failure Forms 402–C and 402–L

Reapprove this form with the following revisions:

On page 4–3–11 of this form, in Par. 13, which contains a tabulation of figures for assisting in converting rail tonnage into track miles for the different weights of rail, there is included the 140 PS section, which in 1954 was adopted as the 140 RE section. In line with this previous Association action, change the tabulation to show the 140 RE section instead of the 140 PS section.

Since several railroads are now purchasing the 119-lb and 136-lb Colorado rail sections, include these two sections in the tabulation in Paragraph 13 of the form (in appropriate location as to weight), as follows:

119 CF&I ..... 186.69 tons
136 CF&I ..... 214.03 tons

Page 4–M–1

APPLICATION OF WELDED BONDS

Reapprove with the following revision:

Change present heading "Application of Welded Bonds" to "Application of Rail Bonds," since this document refers to both pin-connected bonds and welded bonds.

Report on Assignment 2

Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest

B. R. Meyers (chairman, subcommittee), C. B. Bronson, C. J. Code, L. S. Crane, W. J. Cruse, E. B. Fields, J. C. Jacobs, K. K. Kessler, Ray McBrian, L. T. Nuckols, Embert Osland, W. C. Perkins, G. L. Smith, R. P. Winton.

This committee is currently sponsoring two studies at the University of Illinois which are reported on by Professor R. E. Cramer.

1. See Appendix 2–a for report on "Investigation of Failures in Control-Cooled Rails."
2. Report on shelly rail is included as an appendix to the report on Assignment 8.

The committee and the manufacturers have continued discussion to determine the advisability of changing the definition of so-called high-carbon rail, Art. 17, Par. (e) of the rail specifications, so that blue-end rails would be restricted to those which are above the mean percentage in both carbon and manganese. This matter will require further investigation before decision is made.

The manufacturers submitted a proposed specification for 78-ft rail which is now under consideration by Subcommittee 10.

At the request of the committee, the manufacturers will study various means of eliminating burrs at the edges of rail bolt holes and report back to the committee.

Other changes in specifications are under discussion, including dimensions of easement for joint bars and protective coatings for track bolts.

Appendix 2–a

Investigation of Failures in Control Cooled Railroad Rails

By R. E. Cramer

Research Associate Professor, University of Illinois

Organization and Acknowledgement

This investigation is financed equally by the Association of American Railroads and the Technical Committee on Rails of the American Iron and Steel Institute.

Student assistants D. L. Hare and W. B. Crum have worked for this investigation on a part-time basis during the past year.

Control-Cooled Rails Which Failed in Service

Since October 1, 1954, reports have been prepared on 43 failed control-cooled rails. These reports were sent to the railroad engineers supplying the rails, and copies were sent to the rail mills and the director of engineering research, AAR, for the Association's rail failure statistics.

Table 1 gives a summary of these 43 failures, and Table 2 lists each rail separately. There were no transverse fissures from shatter cracks in these 43 failed control-cooled rails and no rails which contained shatter cracks.

Table 1—Summary of Rail Failures

Transverse fissures from hot torn steel	8
Detail fractures from shelling	24
Fractures from welded engine burns	5
Head and web separation	1
Engine burn fracture	1
Bolt hole fracture	1
Shelling only	1
Detail fracture from head check	1
Web failure at stamped heat number	1
Total	43

Table 2—FAILED CONTROL-COOLED RAILS EXAMINED BETWEEN OCTOBER 1, 1954 AND OCTOBER 1, 1955

T.F. = Transverse Fissure; D.F. = Detail Fracture; E.B. = Engine Burn.

Source of Failed Rail	Laboratory Failed Rail Number	Size of Rail	Mill	Heat Number Rail Letter Ingot Number	Date Rolled	Classification of Failure
N & W	857	132	Steelton	81679-B-18	11-1950	T.F. from Hot Torn Steel
C & O	858	131	Inland	35087-E- 4	2-1942	Fracture from Welded E.B.
B & O	859	140	Steelton		7-1950	T.F. from Hot Torn Steel
NP	860	112	Colorado	11628-E-21	1941	Head & Web Separation
T & NO	861	113	Colorado	6181-C- 4	3-1944	D.F. from Shelling
T & NO	862	113	Colorado	11296-A- 6	6-1942	D.F. from Shelling
CP	863	100	Algoma	6130-E	6-1945	D.F. from Shelling
C & O	864	131	E. Thomson	205062-B-3	1-1937	E.B Fracture
C & O	865	131	E. Thomson	204045-B-3	2-1937	Fracture from Welded E.B.
NYC & St.L	866	131	Lackawanna	8131-D-20	1944	T.F. from Hot Torn Steel
B & O	867	140	Steelton	81035-B- 6	10-1948	T.F. from Hot Torn Steel
CP	868	100	Algoma	274v-B-11	3-1947	T.F. from Hot Torn Steel
C & O	869	131	Gary	620800-D-25	4-1945	Fracture from Welded E.B.
B & M	870	112	Lackawanna	5078-E-17	3-1946	D.F. from Shelling
Erie	871	132	E. Thomson			Bolt Hole Failure
CP	872	100	Algoma	1702-C-12	3-1944	T.F. from Hot Torn Steel
C & O	873	131	Steelton	82082-D- 9	2-1941	Fracture from Welded E.B.
C & O	874	131	Steelton	88222-D-15	4-1942	D.F. from Shelling
C & O	875	131	Steelton	88531-G- 6	11-1947	Shelling Only
C & O	876	131	Steelton	89459-F-44	11-1947	D.F. from Shelling
C & O	877	131	Gary	84069-E- 7	2-1938	D.F. from Shelling
C & O	878	131	Gary	710128-B-6	3-1944	D.F. from Shelling
C & O	879	131	Gary	49004-A-22	1-1940	Fracture from Welded E.B.
C & O	880	131	Gary	510306-A-10	6-1944	D.F. from Shelling
C & O	881	131	Gary	812151-A-3	10-1947	D.F. from Shelling
C & O	882	131	Gary	29006-A- 6	1-1940	D.F. from Shelling
C & O	883	131	Gary	590112-C-19	3-1944	D.F. from Shelling
C & O	884	131	Inland	22928-B-13	1-1939	D.F. from Shelling
No Rail No.	885					
CRI & P	886	112	Inland	26555-I-11	1938	D.F. from Shelling
NYC & St.L	887	131	Lackawanna	10609-E-23	11-1947	T.F. from Hot Torn Steel
T & NO	888	113	Colorado	3328-A- 8	7-1942	D.F. from Shelling
T & NO	889	113	Colorado	1352-C- 6	7-1942	D. F. from Shelling
Southern	890	131	Steelton	81278-B- 5	6-1943	T.F. from Hot Torn Steel
Southern	891	100	Tennessee	823518-	12-1941	Web Failure at Stamped Number
C & NW	892	112	Inland	19176-I- 2	5-1940	D.F. from Shelling
C & NW	893	112	Inland	19176-H- 8	5-1940	D.F. from Shelling
C & NW	894	112	Inland	19176-E-10	5-1940	D.F. from Shelling
C & NW	895	112	Inland	19176-D-10	5-1940	D.F. from Shelling
C & NW	896	112	Inland	19176-B- 9	5-1940	D.F. from Shelling
C & NW	897	112	Inland	19176-G- 8	5-1940	D.F. from Shelling
No Rail No.	898					
B & O	899	140	Steelton		1948	D.F. from Shelling
CRI & P	900	112	Inland	27352-A-16	3-1938	D.F. from Shelling
T & NO	901	113	Colorado	2388-B-11	7-1949	D.F. from Shelling

Transverse Fissures from Hot Torn Steel

The eight transverse fissures from hot torn steel were in rails from the following mills rolled in the years indicated:

Steelton—1943, 1948, 1950 (2)
Lackawanna—1944, 1947
Algoma—1944, 1947

Fig. 1 shows two of the transverse fissures from hot torn steel. The fracture at the top left shows an unusual amount of porosity and only a small amount of fatigue area. It is quite probable that a detector car could have located this rail defect before any fatigue growth had developed. The slice from this rail, lower left, also shows many additional large holes in the remainder of the rail head. The upper right picture in Fig. 1 shows a 40 percent transverse fissure from a small porous nucleus, and the etched slice below shows a medium amount of porosity in the etched slice from this rail head.

Detail Fractures from Shelling

There were 24 rails received which contained detail fractures from shelling which will be considered in a separate report on shelly rails. A few of these failures were incorrectly classified as transverse fissures by the railroad men who examined the rails. However, more of these failures did not break at the detector car mark and were sent to the laboratory to find and classify the failures. A few were sent to the laboratory to study the internal conditions of the rail steel which might give more information on the causes of shelly rail failures.

Fractures from Welded Engine Burns

Five of the failed control-cooled rails were fractures from welded engine burns. Special studies are being made on such failures to try to determine what imperfections in the welds caused the subsequent failures to develop. Fig. 2 shows two of the failed welded engine burns. The upper left picture of rail 865 is a cross section through the weld, showing two small holes along the bottom of the weld deposited metal. The bottom left picture is a photomicrograph of this weld, showing a fatigue crack which goes through holes along the bottom of the weld. When such porosity is found in failed welds, it is assumed the holes are the cause of the failure.

Another cause for the failure of a welded engine burn is shown in the two pictures on the right side of Fig. 2 of rail 858. The top photograph shows the fracture covering about 70 percent of the head area. The bottom picture is a photomicrograph at about 70× magnification, showing decarburization along a crack in the original rail steel. We assume this crack was not removed before the engine burn was welded, and the gases from the welding torch caused the decarburization along the crack left in the rail steel.

It is assumed the failure developed from the crack not being removed prior to building up the engine burn in the rail. Rail 869, another fracture from welded engine burn, was carefully examined and holes were found along the bottom of the weld deposited metal. Rail 873 was similarly studied and a crack found which had been carburized during the welding operation. Porosity was found in rail 879. Of the five failed fractures from welded engine burns carefully examined, three appear to have started from porosity at the bottom of the weld deposited metal and two from cracks left in the rail steel or not removed prior to building up the engine burns.

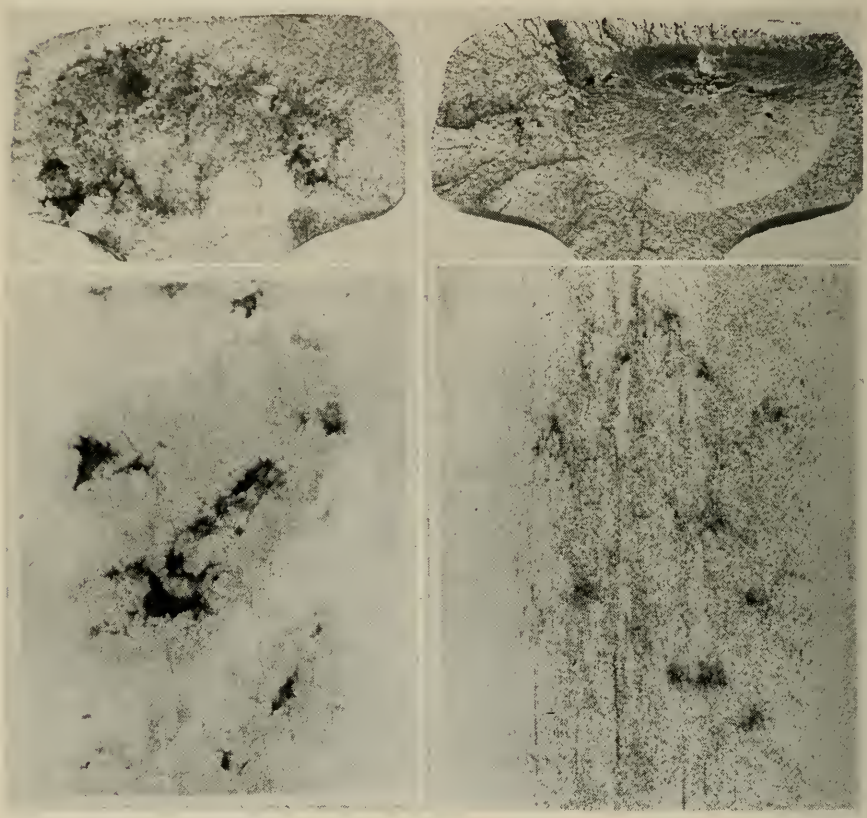


Fig. 1—Two transverse fissures from hot torn steel.

Upper left, rail 859—Fracture as received. Heavy porosity with small amount of fatigue area.

Lower left, rail 859—Slice from rail head showing large holes caused by hot tearing of steel during rolling of rail. Light etch in hot 50 percent hydrochloric acid.

Upper right, rail 857—Forty percent transverse fissure from hot torn steel.

Lower right, rail 857—Etched slice from rail head showing medium porosity. Etched in hot 50 percent hydrochloric acid.

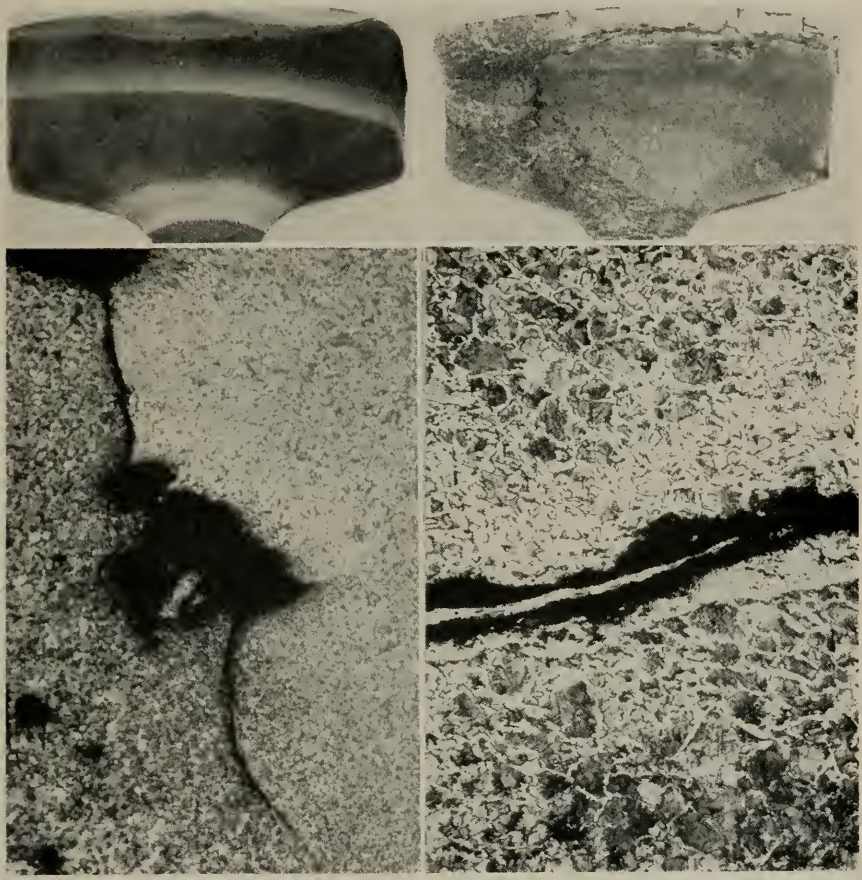


Fig. 2—Two failed welded engine burns.

Upper left, rail 865—Cross section near fracture, etched by ammonium persulfate. Shows porosity along lower edge of weld metal.

Lower left, rail 865—Photomicrograph (about 50× magnification) showing small fatigue cracks starting at porosity.

Upper right, rail 858—Seventy percent fracture from welded engine burn.

Lower right, rail 858—Photomicrograph (about 70× magnification), etch 2 percent nital, showing decarburized rail steel along crack. This crack was not removed before engine burn was welded.

Head and Web Separation Failure

One 112-lb rail, No. 860, was examined to determine the nature of the head and web separation cracks. This rail was supplied as typical of 432 such failures found at insulated joints in 180 miles of track. So far, such failures have not been found in conventional joints in this track. The top picture of Fig. 3 shows the head and web separation crack after etching in hydrochloric acid. The presence of several short cracks on different levels which have not yet joined together is typical of fatigue cracks forming in an area of high stresses. It will also be noticed that there are light corrosion pits on the side of the rail web.

A short section was sawed off the end of the rail before it was etched in acid. This piece was used for metallographic examination of the cracks. The lower picture in Fig. 3 shows two of these cracks at about 80× magnification which are transverse to the rail web. The left end of the picture is the side of the rail web. It will be noted that these cracks are very wide and irregular compared to their length and are much wider near the surface of the web and taper down to a thin fatigue crack at the inside end. The width and roughness of these cracks is caused by corrosion, and the dark material along the cracks is iron oxide. This appearance of the cracks may be considered proof that the head and web separation failures are from corrosion fatigue in the insulated joints. Web failures are discussed quite thoroughly by C. J. Code in an article entitled "Web Failures and Their Prevention," printed in Railway Track and Structures, November 1954, pages 49–51.

The remaining five failures were one each of engine burn fracture, both hole failure shelling only, detail fracture from head check, and web failure at a stamped heat number, all of which were typical of their type of failure.

Summary

1. There were no transverse fissures from shatter cracks in 43 failed control-cooled rails and no rails which contained shatter cracks.

2. Table 1 gives a summary of the classification of the 43 failed control-cooled rails. Table 2 lists each rail separately.

3. Fig. 1 shows two transverse fissures from hot torn steel, one with extra large porosity in the rail.

4. Five fractures from welded engine burns were examined (see Fig. 2). Three appear to have failed from porosity at the bottom of the weld deposited metal and two apparently developed from cracks not removed before making the welds.

5. One head and web separation failure (see Fig. 3), representing 432 track failures in insulated joints, was examined. It was determined that the cracks were the results of corrosion fatigue.

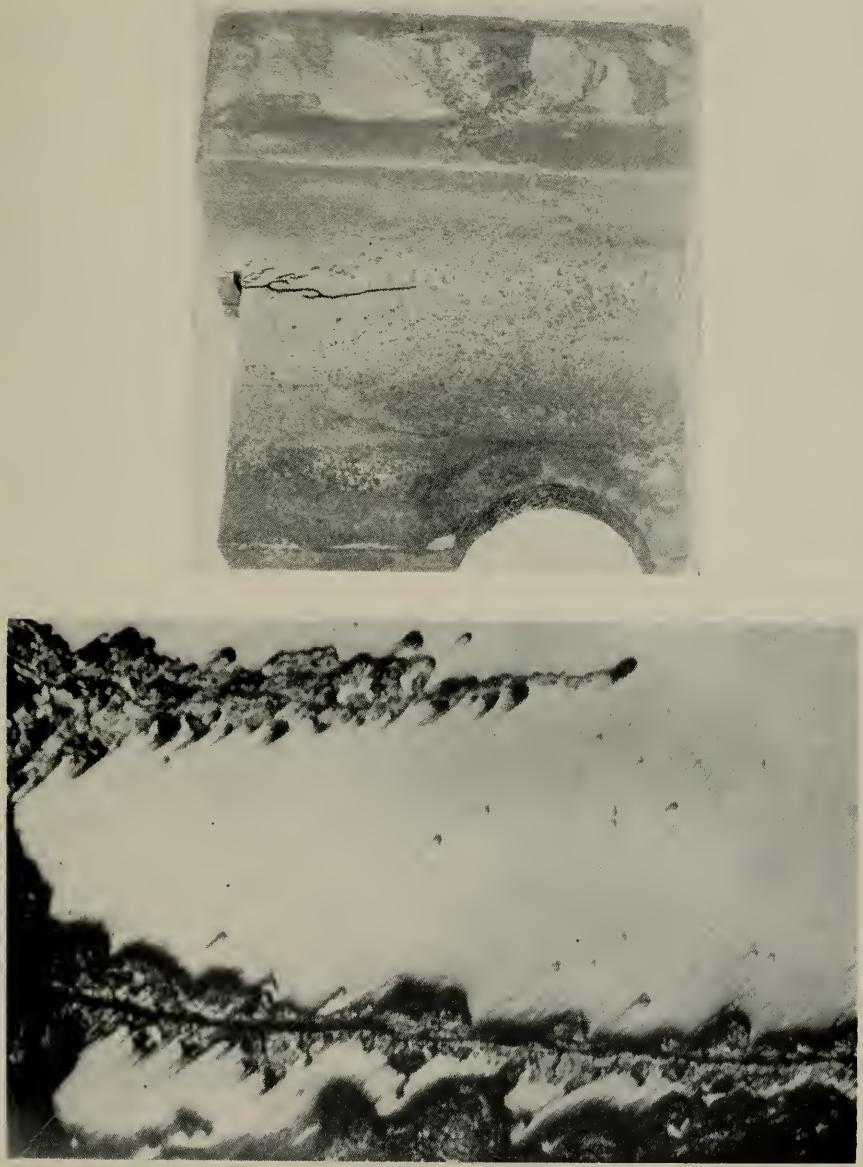


Fig. 3—Head and web separation crack from corrosion fatigue.

Top, rail 860—Rail end showing head and web separation crack. Etched in hot 50 percent hydrochloric acid.

Bottom, rail 860—Photomicrograph showing corrosion along fatigue crack. Unetched. Magnification about 80×.

Report on Assignment 3

Rail Failure Statistics, Covering (a) All Failures; (b) Transverse Fissures; (c) Performance of Control-Cooled Rail

C. J. Code (chairman, subcommittee), F. W. Biltz, B. Bristow, C. B. Bronson, L. S. Crane, J. K. Gloster, W. H. Hobbs, N. W. Kopp, B. R. Meyers, L. T. Nuckols, Embert Osland, G. L. P. Plow, J. G. Roney, S. H. Shepley, A. A. Shillander, H. F. Whitmore.

These statistics present the rail failures reported to December 31, 1954, and are submitted as information. They include the failures reported by 62 railroads on all of their main-line railway mileage, which constitutes 90 percent of all of the main-line track in the United States and Canada. This report was prepared by Kurt Kannowski, metallurgical engineer of the AAR Engineering Division research staff, under the direction of G. M. Magee, director of engineering research.

The accompanying tables and diagrams have been prepared to indicate the extent of control of the transverse fissure problem that has been obtained by the use of control-cooled rail and detector car testing; to give data on the quality of each year's rollings for the various mills; and to show the types of failures that are occurring on the various railroads as related to the mill producing the rail.

Transverse Fissure Failures

The number of service transverse fissure failures, as shown by curves "A" and "C" on Fig. 1, continue to show a decrease. Comparing the data of Table 1, we find for the 62 roads reporting that the service transverse fissure failures decreased from 1207 in 1953 to 913 in 1954, a reduction of 24 percent. This reduction of 24 percent, compared to a reduction of 8 percent last year, is, indeed, a gratifying performance. The detector car mileage as reported by 59 roads in 1953 was 212,280 track miles tested; as reported by 56 roads in 1954, it was 201,134 track miles tested. For the 53 roads reporting in both years, the track miles tested were 193,906 in 1953 and 195,428 in 1954, indicating only a slight increase in detector car testing for 1954. The substantial reduction in service failures is, therefore, indicative of the effect of control-cooled rail and of more effective defect detection in locating and removing transverse defects before service failure occurs.

It is of interest to note that most roads decreased their transverse fissure service failures. Last year it was noted that there was a considerable decrease (4040) in the number of detected transverse defects, as is shown by Curve "B", Fig. 1. This year there was a sizeable increase in detected transverse defects (3238), as shown by curve "B", Fig. 1. The fact that control-cooling has not resulted in a continuing decrease in detected transverse defects since 1943 is because of the number of detected detail fractures from shells and head checks, which are not affected by the control-cooling process.

Table 2 has been prepared to give information on the number of detected transverse fissures as contrasted with the number of total detected transverse defects. In this table are included failures on those railroads that break all detected defects and verify the type of failure. The data in this table are also shown in Fig. 1, and it will be observed that the detected transverse fissures (Curve D) have declined almost continuously since 1943. The amount of this decline is more than would be expected from the tonnage of control-cooled rail now in service. Replacement of heats of rail which have developed transverse fissures in service, and the application of control-cooled rail to the heaviest traffic carrying trackage no doubt explain the effectiveness obtained from the tonnage of control-cooled rail now in use.

From year to year, some roads have discontinued the practice of breaking all detected transverse defects for verification of transverse fissures while other roads have inaugurated this practice. The total for all roads reported in Table 2 is not substantially affected by these changes in any year and the comparison thus afforded is sufficiently accurate for the purpose used.

Mill Performance

Figs. 2 and 3 are presented to show the quality of the rail from the various mills for each year's rollings, as indicated by the failures which develop. Fig. 2, which gives the failures during the first five years of service for all mills collectively, shows that the failure rate has declined steadily and substantially. For the 1948 rollings it is the lowest so far reported and only slightly more for the 1949 rollings. This speaks well for improvements made in mill quality, rail design, and railway maintenance practices.

The accumulated failures by mills and year of rolling, given in Fig. 3, show that for certain mills and certain years the failure rate has been considerably above normal. These instances have been explained in the last two years' reports up to 1953. The 1953 rollings show a high rate at the Dominion and Lackawanna mills. The high rate of failures at the Dominion mill is largely due to a 50 percent increase in failures due to vertical split heads and other head failures reported by the Canadian Pacific Railway. The high rate of failures in the 1952 rolling of the Lackawanna mill is due to other head failures reported by the New York Central, and the high rate in the 1953 rollings is due to the same cause, together with an increase in other head failures reported by the Boston and Maine and the Northern Pacific.

Table 3 shows that the amount of rail laid increased from 897,278 tons in 1952 to 1,097,984 tons in 1953. This raises the number of track miles laid with control-cooled rail since 1935 to 100,263.03. Assuming that most of this rail is still in main track, this would indicate that about 42 percent of main track is now laid with control-cooled rail.

The shape of the line in Fig. 4 is interesting in comparing the failure rate with respect to years of service. The failures reported for the various years of service each represent a different year's rolling. They, therefore, include, in addition to the effect of the length of the service period any difference in mill quality and traffic density. Nevertheless, this figure over the past years has consistently shown a low failure rate for the first 5 or 6 years of service, followed by a marked increase in failure rate up to the ninth year. Generally, the tenth year has shown a decrease in rate, due to replacement of rail which has had an abnormal number of failures deevlop during its service use.

Types of Failures

Tables 6 and 7 have been prepared to give information on the types of failures in control-cooled rail. It will be noted that web failures within the joint bar limits and detail fractures are the 2 outstanding types of failures, representing 35 percent and 38 percent, respectively, of all failures reported. Comparing failures of all types per 100 track miles reported for 1953 (8.15) with the failures reported for 1954 (7.74), there is a decrease in every type of failure except in detail fractures, which increased from 2.82 failures per 100 track mile years in 1953 to 2.98 in 1954.

The decrease in failures within the joint bar limits is expected to become more pronounced as the new rail sections with improved web and fillet designs and bolt hole spacings constitute a larger proportion of rail in main track. It is interesting to note that these failures would have been reduced more this year if the Missouri Pacific

(Text continued on page 814)

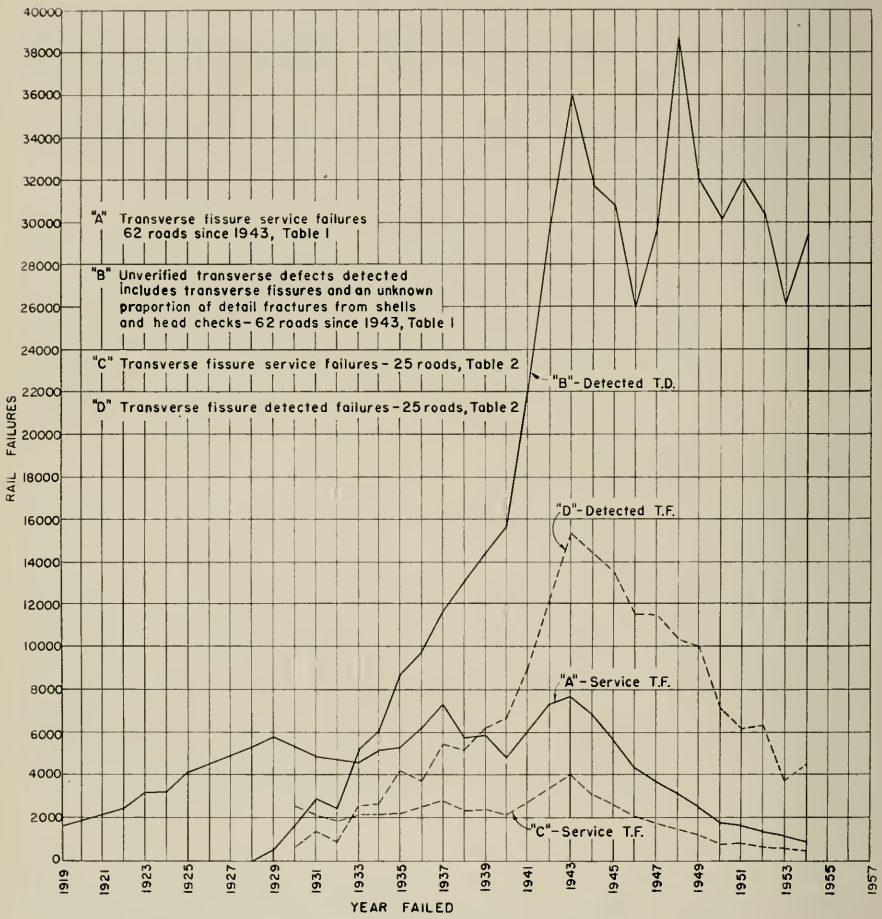


FIG. 1 – ANNUAL SERVICE RAIL FAILURES DUE TO TRANSVERSE FISSURES AND TO DETECTED TRANSVERSE DEFECTS AS REPORTED BY ALL RAILROADS.

FIG. 2- SERVICE AND DETECTED FAILURES IN UNITED STATES AND CANADA

Fig. 3 - Control Cooled Rail Failure Rates to December 31, 1953 by Mills - All Types Except Engine Burn Failures - Service and Detected.

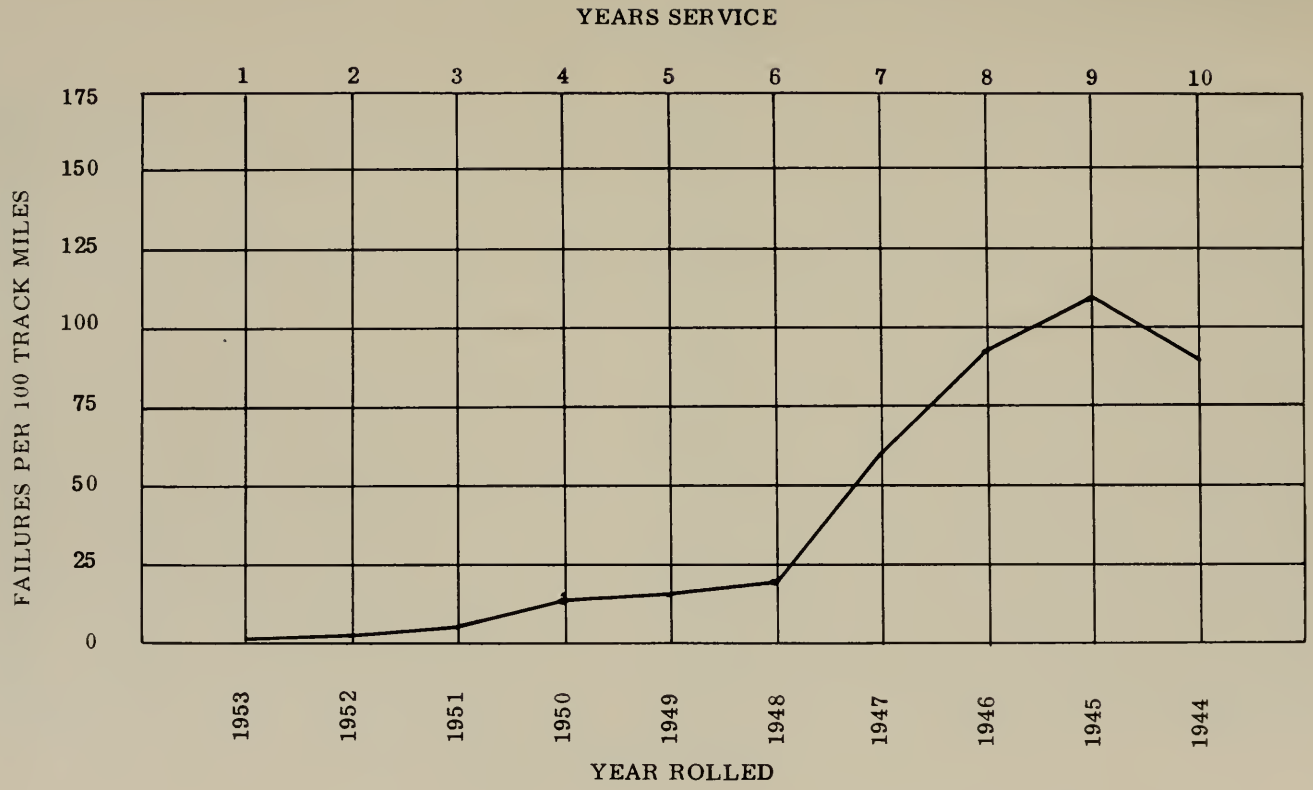


Fig. 4 - Control Cooled Rail Failures to December 31, 1954 Per 100 Track Miles - All Types Excluding Engine Burn Fractures - Service and Detected.

TABLE 1 - SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED FAILURES FROM TRANSVERSE DEFECTS BY RAILROADS AND BY YEAR FAILED - ALL ROLLINGS BY ALL PROCESSES

	Service Failures											Detected Failures										
Yr. Failed	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total
AT&SF	141	157	112	92	103	39	52	54	18	19	787	538	580	388	1358	1449	1110	1169	1088	970	908	9558
ACL	50	51	43	14	7	12	9	4	7	4	201	1302	924	1120	1491	919	944	758	741	853	851	9903
B&O	332	205	209	177	100	156	100	91	100	76	1546	844	978	801	713	780	733	745	641	596	696	7527
B&OCT	0	0	12	9	5	1	2	0	2	4	35	0	0	0	2	15	5	2	2	0	3	29
BanAroos	3	1	2	0	0	1	0	0	0	1	8	0	49	0	26	16	19	7	11	24	22	174
B&LE	6	9	3	5	3	3	2	2	5	0	38	0	0	0	0	0	0	0	138	36	0	174
B&M	17	11	26	31	16	14	7	24	21	25	192	695	315	212	379	300	375	356	311	292	284	3519
CP	274	214	184	181	131	77	75	47	47	31	1261	4957	3105	4338	3546	3787	2866	3800	4251	1504	1805	33959
Cof Ga	58	31	40	31	18	17	24	14	12	10	255	157	184	0	426	275	274	243	301	0	367	2227
C&O - Ches	57	68	88	64	37	22	29	43	21	16	445	458	465	559	1108	845	512	637	678	680	559	6501
C&O - PM	1	1	0	0	0	0	0	0	0	0	2	27	23	0	11	5	2	6	6	3	3	86
C&EI	62	57	42	33	41	17	15	21	18	19	325	304	338	316	317	320	265	212	97	150	206	2525
C&NW	135	137	168	149	118	84	85	74	72	62	1084	1641	1176	1461	976	1159	816	1216	817	836	861	10959
CB&Q	244	141	152	144	65	59	59	28	23	17	932	1342	1408	885	954	975	465	679	687	463	940	8798
CI&L	16	8	6	7	0	4	4	5	2	5	57	21	57	2	114	77	151	80	58	58	75	693
CMStP&P	132	79	87	89	61	48	42	45	44	30	657	1083	1069	1173	914	1080	675	763	733	982	928	9400
CRI&P	168	123	127	83	47	48	56	46	49	27	774	643	527	552	596	620	445	369	537	322	412	5023
C&S	21	3	10	3	5	2	0	4	-	2	50	47	82	17	189	72	164	55	182	-	308	1116
D&H	31	14	19	12	12	6	10	10	5	0	119	196	114	111	314	508	306	430	367	327	314	2987
DL&W	29	36	22	17	8	7	3	5	-	-	127	300	303	375	319	186	270	225	257	-	-	2235
D&RGW	212	159	22	31	15	16	14	-	-	6	475	254	190	14	695	373	741	645	-	-	455	3367
Erie	99	98	87	58	43	24	19	20	19	9	476	549	666	619	776	570	543	475	459	435	469	5561
FEC	92	67	86	55	39	27	1	7	0	0	374	119	164	279	182	243	26	13	30	94	175	1325
GTW	43	13	20	27	19	11	9	7	16	6	171	112	83	89	110	123	118	85	71	96	74	961
GN	247	266	175	175	+102	85	94	63	47	45	1299	535	516	430	1531	936	1167	1069	1525	932	1163	9804
GM&O	54	-	26	35	-	-	-	-	-	-	115	60	-	265	274	-	-	-	-	-	-	599
IC (Sys)	197	64	65	59	69	53	55	28	33	25	648	1907	1314	1418	1650	1284	1296	1226	1279	1088	908	13370
JCL	48	45	61	65	37	48	14	14	11	9	352	0	3	0	0	0	0	0	56	15	56	130
KCS	21	4	0	10	8	4	6	6	0	8	67	66	94	0	94	73	100	93	94	89	58	761
L&HR	0	0	4	0	0	0	1	1	0	0	6	13	12	6	0	0	0	11	8	8	6	64
L&NE	2	7	2	5	0	0	0	1	0	2	19	15	16	13	36	4	12	12	12	0	14	134
LV	49	22	22	14	6	14	12	20	8	2	169	156	67	127	55	126	87	163	105	108	123	1117

TABLE 1 (Continued)

	Service Failures											Detected Failures										
Yr. Failed	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total
LI	-	-	-	-	0	0	0	0	0	0	0	-	-	-	-	25	26	18	25	15	14	123
L&N	159	116	133	115	60	48	63	40	40	29	803	684	648	653	933	864	743	843	926	711	592	7597
Me. Cen.	15	14	0	0	7	6	2	3	2	-	49	63	50	0	0	74	130	89	55	46	-	507
MStP&SSM	49	23	30	21	17	11	11	6	0	0	168	24	96	90	95	73	104	116	138	81	632	1449
MKT	57	28	31	30	24	16	19	13	14	8	240	214	141	118	576	532	359	290	162	270	259	2921
MP Lines X	24	31	42	4	24	*57	72	51	42	23	370	399	462	507	553	518	1479	1308	1267	981	783	8257
NC&StL	43	32	19	9	9	7	6	5	4	1	135	184	68	84	104	59	45	43	43	11	3	644
NYC (Sys) #	344	225	202	173	165	154	177	130	155	114	1839	1119	750	724	1484	1508	1306	1344	1284	1151	1612	12282
NYC&StL	47	29	45	37	21	19	16	13	10	9	246	199	215	172	128	118	106	84	77	60	54	1213
NYC Trans.	3	6	2	15	-	-	-	-	-	-	26	0	0	0	0	-	-	-	-	-	-	0
NYNH&H	14	3	5	4	2	3	1	0	2	4	38	74	86	68	172	79	116	77	48	73	56	849
NYO&W	6	1	24	24	12	21	25	10	8	6	137	0	56	2	0	0	11	20	86	110	182	467
N&W	1	5	3	2	3	3	1	3	2	4	27	40	58	17	129	84	130	124	157	113	135	987
NP	288	289	188	129	90	73	11	1	0	0	1069	471	702	475	431	473	347	377	372	417	429	4494
PRR ##	415	290	259	255	430	92	103	85	122	76	2127	909	646	644	1865	1166	1876	1844	1322	1792	1574	13638
P&LE	0	3	0	1	0	0	1	0	0	0	5	6	1	5	36	22	29	12	20	26	22	179
Reading	70	49	47	0	0	0	0	0	0	0	166	735	287	321	1236	404	241	451	205	396	460	4736
RF&P	27	20	12	10	6	1	0	0	1	0	77	207	176	106	514	195	172	128	64	55	25	1642
Rutland	1	2	1	0	0	0	4	0	2	2	12	0	0	9	0	0	0	28	0	0	0	37
StL - SF	142	102	101	74	52	17	16	0	3	5	512	655	415	532	664	639	515	377	410	398	346	4951
SAL	23	24	21	11	18	22	7	14	7	12	159	159	299	440	412	299	454	324	318	344	344	3393
SP	267	209	179	162	98	68	75	76	69	63	1266	1377	1362	909	1243	1012	952	960	970	1005	728	10518
Southern	277	246	188	171	98	98	106	70	63	41	1358	1955	1835	1998	2643	2009	1927	1682	1490	1622	2157	19318
T&NO	186	123	66	112	99	90	88	79	55	28	926	924	837	739	951	1006	958	788	749	606	708	8266
T&P	124	72	71	46	22	16	8	7	5	6	377	582	524	0	393	173	152	114	90	70	115	2213
UP	241	176	172	55	19	23	13	15	13	18	745	1356	1148	4957	4149	3613	3429	4142	4157	4632	5003	36586
Virginian	13	10	4	6	1	0	0	1	0	0	35	0	0	0	152	24	60	73	45	39	41	434
W. Md.	27	14	33	25	3	16	15	14	8	4	159	133	144	224	418	302	138	133	156	153	59	1860
W&LE	3	5	1	0	3	7	-	-	-	-	19	3	3	0	8	5	11	-	-	-	-	30
ALL ROADS	5707	4238	3801	3166	2398	1767	1639	1320	1207	913	26156	30813	25831	29364	38445	32396	30303	31333	30178	26138	29376	304177

*Includes all transverse defects
-No report received

#Includes IHB failures
##Including LI RR and PRSL 1940 to 1948 inclusive
+Includes engine burn fractures
XReported separately as MPRR and MP Lines in previous years

TABLE 2 - SERVICE AND VERIFIED DETECTED TRANSVERSE FISSURE FAILURES BY RAILROAD AND BY YEAR FAILED REPORTED BY ROADS WHICH BREAK THEIR DETECTED RAILS. ALL ROLLINGS BY ALL PROCESSES.

	Service Failures											Detected Failures										
Yr. Failed	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total
AT&SF	141	157	112	92	103	39	52	54	18	19	787	538	580	388	298	488	359	362	308	213	0	3534
Ban & Aroos	3	1	2	0	0	1	0	0	0	1	8	0	49	0	26	11	19	7	11	24	22	169
CP	274	214	184	181	131	77	75	47	47	31	1261	4957	3105	4338	3545	3787	2866	1900	2125	0	1	26624
C of GA.	58	31	40	31	18	17	24	14	12	10	255	-	-	-	-	-	-	-	-	-	66	66
C&EI	62	57	42	33	41	17	15	21	18	19	325	304	338	316	312	320	245	187	97	0	0	2119
CB&Q	244	141	152	144	65	59	59	28	23	17	932	1342	1408	885	887	884	426	528	544	372	420	7696
CMStP&P	132	79	87	89	61	48	42	45	44	30	657	1083	1069	1173	734	901	557	567	495	546	571	7696
C&NW	135	137	168	149	118	84	85	74	72	62	1084	-	-	-	-	-	-	-	-	-	6	6
CRI&P	168	123	127	83	47	48	56	46	49	27	774	-	-	-	-	-	-	-	-	-	1	1
C&S	21	3	10	3	5	2	0	4	-	2	50	47	82	17	56	37	53	45	71	-	131	539
Erie	99	98	87	58	43	24	19	20	19	9	476	549	666	619	595	469	463	350	276	326	336	4649
GTW	43	13	20	27	19	11	9	7	16	6	171	112	83	89	106	123	118	85	71	96	74	957
GN	247	266	175	175	102	85	94	63	47	45	1299	535	516	430	631	599	519	546	662	362	433	5233
LI*	-	-	-	-	0	0	0	0	0	0	0	-	-	-	-	25	26	18	25	15	0	109
L&N	159	116	133	115	60	48	63	40	40	29	803	684	648	653	662	554	483	524	300	545	0	5053
MStP&SStM	49	23	30	21	17	11	11	6	0	0	168	-	-	-	-	-	-	-	-	-	10	10
MKT	57	28	31	30	24	16	19	13	14	8	240	214	141	118	280	264	176	265	157	266	214	2095
MP Lines X	24	31	42	4	24	10	28	8	8	23	202	-	-	-	-	-	-	-	-	-	557	557
NC&StL	43	32	19	9	9	7	6	5	4	1	135	184	68	84	87	58	39	34	38	10	0	602
NYC (Sys)	344	225	202	173	165	154	177	130	155	114	1839	1119	750	724	690	693	673	684	722	759	1220	7998
NYC&StL	47	29	45	37	21	19	16	13	10	9	246	199	215	172	128	116	0	0	77	60	54	1021
NYNH&H	14	3	5	4	2	3	1	0	2	4	38	74	86	68	132	60	107	64	43	57	45	736
NYO&W	6	1	24	24	12	21	25	10	8	6	137	-	-	-	-	-	-	-	-	-	68	68
N&W	1	5	3	2	3	3	1	3	2	4	27	40	58	17	29	28	32	16	36	19	40	315
NP	288	289	188	129	90	73	11	1	0	0	1069	471	702	475	355	441	41	22	68	58	87	2720
PRR	415	290	259	255	430	92	103	85	122	76	2127	909	646	644	404	16	-	-	-	-	-	2619
P&LE	0	3	0	1	0	0	1	0	0	0	5	6	1	5	0	0	3	3	7	9	0	34
RF&P	27	20	12	10	6	1	0	0	1	0	77	207	176	106	147	49	22	12	0	1	13	733
Rutland	1	2	1	0	0	0	4	0	2	2	12	0	0	9	0	0	0	14	0	0	0	23
Va.	13	10	4	6	1	0	0	1	0	0	35	0	0	0	1	0	0	0	0	3	0	4
W Md.	27	14	33	25	3	16	15	14	8	4	159	133	144	224	210	141	66	77	81	25	59	1160
Total	3142	2441	2237	1910	1620	986	1011	752	741	558	15398	13707	11531	11554	10315	10064	7293	6274	6214	3766	4428	85146

*Included in PRR prior to 1949.

-No report received.

X Reported separately as MPRR and MP Lines in previous years

TABLE 3 - TONS OF RAILS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1944 - 1953 INCL., REPORTED BY 61 RAILROADS.

Year Rolled	OH CONTROL COOLED ONLY		BRUNORIZED AND OTHER PROCESS		TOTAL	
	TONS	TRACK MILES	TONS	TRACK MILES	TONS	TRACK MILES
1944	1,517,408	8,183.03	7,845	54.12	1,525,253	8,237.15
1945	1,487,946	7,951.68	0	0	1,487,946	7,951.68
1946	1,220,396	6,469.42	0	0	1,220,396	6,469.42
1947	1,393,935	7,236.28	0	0	1,393,935	7,236.28
1948	1,279,778	6,601.31	0	0	1,279,778	6,601.31
1949	1,140,253	5,966.41	0	0	1,140,253	5,966.41
1950	1,191,853	6,335.78	0	0	1,191,853	6,335.78
1951	1,117,510	5,908.58	0	0	1,117,510	5,908.58
1952	897,278	4,796.63	0	0	897,278	4,796.63
1953	1,097,984	5,683.69	0	0	1,097,984	5,683.69
TOTAL	12,344,341	65,132.81	7,845	54.12	12,352,186	65,186.93

TABLE 4 - SERVICE AND DETECTED FAILURES OF ALL TYPES EXCEPT ENGINE BURN FAILURES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1954 PER 100 AVERAGE TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS, FROM ALL MILLS.

Year Rolled	YEARS OF SERVICE									
	1	2	3	4	5	6	7	8	9	10
1944	3.6	7.2	13.8	19.4	33.3	46.1	61.2	84.6	105.5	84.3
1945	1.4	4.1	8.6	15.7	28.8	43.9	65.8	87.4	110.8	
1946	1.2	2.9	6.6	12.9	25.1	41.0	57.8	94.2		
1947	0.9	3.1	6.5	13.6	25.5	39.6	62.5			
1948	0.7	1.6	3.6	7.5	11.5	19.1				
1949	1.7	4.1	7.2	10.0	15.8					
1950	3.1	6.0	9.6	14.1						
1951	2.0	3.4	5.0							
1952	2.0	2.8								
1953	0.8									

TABLE 5 - TRACK MILES AND 1954 FAILURES, ALL TYPES, IN ROLLINGS 1944 TO 1953, INCL., OPEN-HEARTH CONTROL-COOLED RAIL ONLY.

ROAD	TRACK MILES BY MILL										1954 FAILURES	
	ALG	CARN	COLO	DOM	GARY	INLD	LACKA	STLTN	TENN	TOTAL	EBFs EXCL.	EBFs ONLY
AT&SF			2885		1176	196				4257	92	0
ACL		103						778	1132	2013	407	2
B&O		936			343	9	184	626		2098	141	74
B&OCT					13	26				39	0	0
Ban Aroos		3						167		170	2	0
B&LE		102								102	0	0
Bos & Alb					3		164			167	1	0
B&M		86					109	71		266	40	1
CP	4651			686			131			5468	252	0
C of Ga.									386	386	16	0
C&O - Ches E Regn		73			772	477	67	120		1509	146	17
C&O - PM	59				220	100	74			453	1	0
C&EI					167	27				194	19	0
C&NW					785	186	160			1131	57	0
CB&Q			1258		1012	179				2449	18	0
CI&L					108	37				145	0	0
CMStP&P					1447	431				1878	24	0
CRI&P			212		1088	325				1625	14	0
CCC&StL -P&E					637	70	21			728	105	8
C&S			240							240	2	0
D&H								291		291	36	3
D&RGW			522							522	43	0
Erie		626			337	23	126			1112	12	0
FEC		28						90	441	559	1	1
GTW					331	99	74			504	18	0
GN			370		772	257	240			1639	77	0
IC					1425	591			271	2287	44	3
IHB						14				14	0	0
JCL								174		174	0	0
KCS					294	35				329	1	0
L&IR								26		26	0	0
L&NE								43		43	0	0
LV							309			309	3	0
LI								121		121	0	0
L&N					151				1391	1542	105	9
MStP&SSM					276	163	102			561	10	0
MKT			94		427	104				625	6	5
MP Lines			1113		560	164			237	2074	1136	2
NC&StL					5				550	555	15	0
NYC - E					61		1149			1210	132	7
NYC - W					586	37	37			660	71	21
NYC&StL		201			530	111	237			1079	242	0
NYNH&H		155						329		484	112	3
NYO&W							9			9	0	0
N&W		772						257		1029	127	5
NP			524		444	95	278			1341	68	5
PRR		1064			430	79		1226		2799	213	83
P&LE		150								150	70	2
Readiog								522		522	0	0
RF&P								177		177	3	0
Rutland							4			4	0	0
St L - SF					10	50			822	882	4	0
SAL		3						942	532	1477	8	0
SP			3141							3141	381	80
Southern					95			749	1140	1984	62	1
T&NO			661						99	760	13	1
T&P			538						80	618	0	1
UP			2166		834	137				3137	2332	51
Va		79						168		247	5	0
WMd		164						246		410	47	0
TOTAL	4710	4545	13724	686	15339	4042	3475	7123	7081	60725	6734	385

TABLE 6 - ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1944 TO 1953, INCLUSIVE FROM DATE ROLLED TO DECEMBER 31, 1954, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE.

OH CONTROL COOLED RAIL ONLY

MILL	ACCUMULATED FAILURES TO DEC. 31, 1954 (EXCL. EBFs)									ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MI. YEARS
	TF VER U of I	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB IN JT.	WEB OTHER	BASE				
ALGOMA	6	15	237	11	226	112	411	43	984	2045	4711	27090	7.55
CARNEGIE (ET)	10	451	49	73	131	65	1378	149	9	2315	4834	28108	8.24
COLORADO	0	6730	292	643	524	46	666	507	18	9428	14255	83730	11.26
DOMINION	0	0	28	2	13	4	61	8	13	129	684	2313	5.58
GARY	6	1418	111	77	388	222	3788	232	52	6294	15711	90105	6.99
INLAND	10	517	41	17	34	104	302	43	20	1088	4236	22510	4.83
LACKAWANNA	22	169	59	23	170	66	1658	22	86	2275	3590	21545	10.56
STEELTON	22	1046	38	44	80	98	770	84	4	2186	7340	40484	5.40
TENNESSEE	0	295	108	240	192	155	717	127	33	1867	7340	41010	4.55
ALL MILLS	76	10641	963	1130	1760	872	9751	1215	1219	27627	62701	356895	7.74
FAILURES 100 TR. MI. YEARS	.02	2.98	.27	.32	.49	.24	2.73	.34	.34	7.74			

Definition of symbols:

TF - Transverse Fissure
CF - Compound Fissure
DF - Detail Fracture
VSH - Vertical Split Head
HSH - Horizontal Split Head
EBF - Engine Burn Fracture

TABLE 7 - ACCUMULATED FAILURES OF ALL TYPES FOR OH CONTROL COOLED RAIL, ONLY IN ROLLINGS 1944-1953, INCL., ACCUMULATED TO DECEMBER 31, 1954, SERVICE AND DETECTED, SEGREGATED BY ROADS AND MILLS.

ROADS	TF Ver Uofl	CF & DF	VSH	HSH	Other Head	Broken	Web		Base	FAILURES TOTALS			
										EBFs Excl.		EBFs Only	
							In. Jt.	Other		Accum. Total	1954	Accum. Total	1954
ALGOMA													
CP	6	15	237	11	226	112	411	43	983	2044	212	0	0
C&O-PM	0	0	0	0	0	0	0	0	1	1	0	0	0
TOTAL	6	15	237	11	226	112	411	43	984	2045	212	0	0
CARNEGIE													
ACL	0	0	0	0	0	0	71	3	0	74	56	0	0
B&O	0	79	29	16	38	10	130	80	2	384	66	130	45
B&LE	0	2	0	3	0	0	0	0	0	5	0	2	0
B&M	5	5	0	0	25	2	2	0	0	39	12	0	0
C&O-Ches	0	4	0	0	0	0	5	0	0	9	5	2	0
Erie	0	23	1	3	2	1	2	2	0	34	9	3	0
NYC&StL	0	4	4	7	16	13	162	10	0	216	34	0	0
NYNH&H	0	7	6	13	1	4	110	0	0	141	86	4	0
N&W	0	291	4	18	35	0	68	24	6	446	100	11	2
PRR	0	16	2	8	13	7	443	18	1	508	68	368	42
P&LE	0	10	3	2	1	0	385	2	0	403	70	15	2
Va	0	10	0	2	0	15	0	10	0	37	1	0	0
W Md.	5	0	0	1	0	13	0	0	0	19	14	0	0
TOTAL	10	451	49	73	131	65	1378	149	9	2315	521	535	91
COLORADO													
AT&SF	0	130	31	58	13	4	100	1	1	338	83	0	0
CB&Q	0	1	4	5	13	0	9	1	0	33	6	2	0
CRI&P	0	0	2	0	6	19	3	0	2	32	2	0	0
C&S	0	1	0	0	3	0	0	0	0	4	2	0	0
D&RGW	0	201	6	19	4	0	16	0	0	246	43	0	0
GN	0	2	1	0	3	0	1	0	0	7	2	0	0
MKT	0	0	1	0	1	0	0	0	0	2	0	0	0
MP Lines	0	3	8	4	9	2	93	4	0	123	57	19	1
NP	0	0	1	2	39	3	13	4	0	62	31	9	5
SP	0	254	189	447	209	16	401	391	15	1922	381	196	80
T&NO	0	5	4	14	5	1	2	16	0	47	9	2	1
T&P	0	0	1	0	1	1	7	0	0	10	0	1	1
UP	0	6133	44	94	220	0	21	90	0	6602	1796	33	33
TOTAL	0	6730	292	643	526	46	666	507	18	9428	2412	262	121

TABLE 7 - CONTINUED

ROADS	TF Ver Uofl	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1954	EBFs Only Accum Total	EBFs Only 1954
DOMINION													
CP	0	0	28	2	13	4	61	8	13	129	37	0	0
TOTAL	0	0	28	2	13	4	61	8	13	129	37	0	0
GARY													
AT&SF	0	0	3	6	5	5	24	0	0	43	9	0	0
B&O	0	1	6	1	4	1	35	3	3	54	8	49	9
B&OCT	0	0	0	1	0	0	1	0	0	2	0	0	0
Bos & Alb	0	0	0	0	0	0	2	0	0	2	0	0	0
C&O - Ches	2	196	5	1	8	8	43	24	0	287	64	68	3
C&O - PM	0	1	3	1	2	0	0	0	0	7	0	0	0
C&EI	1	0	4	2	18	5	23	2	0	55	16	2	0
C&NW	0	7	3	3	19	42	348	2	5	429	43	2	0
CB&Q	0	0	3	7	3	0	22	7	1	43	9	1	0
CI&L	0	0	1	0	0	0	0	0	0	1	0	0	0
CMStP&P	0	4	3	0	2	32	1	3	4	49	8	0	0
CRI&P	0	0	3	7	6	43	5	3	9	76	7	0	0
CCC&StL	1	4	7	7	24	3	553	66	2	667	100	11	8
Erie	0	19	0	0	0	0	3	1	0	23	1	1	0
GTW	1	0	14	0	5	26	21	2	6	75	13	0	0
GN	0	208	4	2	117	17	29	7	1	385	63	0	0
IC	0	29	11	7	0	5	54	10	3	119	39	11	3
KCS	0	0	3	1	1	1	0	1	0	7	1	1	0
L&N	0	5	1	1	1	0	2	2	0	12	3	0	0
MStP&SStM	0	0	5	0	1	9	0	1	8	24	5	0	0
MKT	0	0	2	1	14	0	10	5	0	32	6	6	5
MP Sys.	1	0	2	2	2	4	1230	3	2	1246	1077	0	0
NC&StL	0	0	1	0	2	0	1	1	0	5	0	0	0
NYC - East	0	40	1	2	0	0	22	0	0	65	10	3	2
NYC - West	0	29	8	2	15	1	618	11	2	686	69	32	21
NYC&StL	0	8	3	7	20	8	409	15	1	471	120	0	0
NP	0	0	4	2	15	6	12	1	1	41	16	0	0
PRR	0	13	3	1	0	5	314	1	1	338	78	5	2
StL - SF	0	0	0	0	2	0	0	1	0	3	0	0	0
Southern	0	0	0	0	3	1	0	2	1	7	2	1	0
UP	0	854	8	13	99	0	6	58	2	1040	415	20	18
TOTAL	6	1418	111	77	388	222	3788	232	52	6294	2182	213	71

TABLE 7 - CONTINUED

ROADS	TF Ver Uofl	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1954	EBFs Only Accum Total	EBFs Only 1954
INLAND													
AT&SF	0	1	0	0	0	0	0	0	0	1	0	0	0
B&O	0	0	1	0	0	0	0	0	0	1	0	0	0
C&O - Ches	3	223	6	1	3	17	29	14	1	297	33	32	13
C&O - PM	0	1	1	1	0	0	0	0	2	5	1	0	0
C&EI	0	0	3	0	3	0	3	1	0	10	3	4	0
C&NW	0	7	6	4	3	11	82	1	4	118	12	0	0
CB&Q	3	0	1	1	2	1	4	0	0	12	3	0	0
CMStP&P	2	12	5	1	3	31	2	2	2	60	16	0	0
CRI&P	1	0	0	2	2	9	1	0	2	17	5	0	0
Erie	0	0	0	0	0	1	0	0	0	1	0	0	0
GTW	0	0	1	0	2	16	5	0	3	27	4	0	0
GN	0	1	3	1	6	0	5	0	0	16	9	0	0
IC	0	5	5	0	0	2	16	0	1	29	3	1	0
IHB	0	0	0	0	0	0	1	1	0	2	0	0	0
MStP&SStM	0	0	1	0	0	9	1	3	4	18	1	0	0
MKT	0	1	3	2	4	0	3	2	0	15	0	1	0
MP Lines	0	1	2	0	0	0	2	0	0	5	1	0	0
NYC - West	0	0	0	0	0	0	2	0	0	2	1	0	0
NYC&StL	0	0	2	1	1	2	119	11	1	137	33	0	0
NP	1	0	0	0	3	1	0	0	0	5	0	0	0
PRR	0	5	0	0	0	3	26	1	0	35	1	0	0
StL - SF	0	0	0	1	0	0	0	0	0	1	0	0	0
UP	0	260	1	2	2	1	1	7	0	274	121	0	0
TOTAL	10	517	41	17	34	104	302	43	20	1088	247	38	13
LACKAWANNA													
B&O	0	9	3	0	5	2	49	7	0	75	22	32	2
Bos & Alb	0	1	1	0	1	0	11	0	2	16	1	0	0
B&M	14	18	3	0	29	3	2	0	1	70	17	2	1
CP	0	0	4	3	10	0	1	0	20	38	3	0	0
C&O - Ches	1	28	0	1	1	0	0	2	0	33	15	0	0
C&NW	0	0	0	2	5	3	5	0	8	23	2	0	0
CCC&StL	0	0	1	0	6	0	6	0	0	13	5	0	0
Erie	0	12	0	0	0	1	0	0	1	14	2	0	0
GTW	0	0	31	1	3	5	1	0	3	44	1	0	0
GN	0	10	1	0	53	0	10	2	5	81	3	0	0
LV	0	1	0	0	0	0	2	1	13	17	3	0	0
MStP&SStM	0	0	1	0	0	18	1	1	9	30	4	2	0
NYC - East	2	82	14	15	38	5	1473	3	6	1638	122	14	5
NYC - West	0	1	0	0	1	0	3	0	0	5	1	0	0
NYC&StL	5	6	0	1	7	8	76	3	0	106	55	0	0
NYO&W	0	0	0	0	0	0	2	0	0	2	0	0	0
NP	0	1	0	0	11	21	16	3	18	70	21	0	0
Rutland	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	22	169	59	23	170	66	1658	22	86	2275	277	50	8

TABLE 7 - CONTINUED

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1954	EBFs Only Accum Total	EBFs Only 1954
STEELTON													
ACL	0	0	0	0	0	0	162	16	1	179	140	0	0
D&O	6	94	10	7	5	2	45	26	0	195	45	58	18
Ban & Aroos	0	0	2	0	0	2	0	0	0	4	2	0	0
B&M	2	10	2	0	14	3	1	0	0	32	11	0	0
C&O - Ches	2	169	4	2	7	0	0	6	0	190	29	3	1
D&H	0	149	2	8	3	2	2	7	0	173	36	3	3
FEC	0	1	0	1	0	0	0	0	0	2	0	1	0
JCL	0	0	0	0	0	0	1	0	0	1	0	0	0
L&HR	0	0	0	0	0	0	0	0	0	0	0	0	0
LI	0	0	0	0	0	0	0	0	0	0	0	0	0
NYNH&H	0	12	3	3	0	0	27	0	0	45	26	8	3
N&W	2	135	0	3	15	0	34	8	1	198	27	4	3
PRR	0	369	5	15	26	22	320	0	0	757	66	175	39
Reading	0	2	0	0	0	2	2	1	0	7	0	0	0
RF&P	1	31	2	0	3	0	165	0	0	202	3	1	0
SAL	0	0	4	1	0	7	3	1	0	16	1	0	0
Southern	0	18	0	0	5	18	3	0	0	44	16	8	0
Va.	2	51	2	2	0	23	5	14	2	101	4	0	0
W Md.	7	5	2	2	2	17	0	5	0	40	33	0	0
TOTAL	22	1046	38	44	80	98	770	84	4	2186	439	261	67
TENNESSEE													
ACL	0	0	2	6	5	3	397	43	2	458	211	6	2
Cof Ga	0	6	6	21	6	3	52	4	9	107	16	14	0
FEC	0	13	0	5	0	1	5	0	0	24	1	14	1
IC	0	1	9	2	0	1	10	3	0	26	2	0	0
L&N	0	241	42	132	18	22	147	34	5	641	102	21	9
MP Lines	0	0	0	1	0	0	1	0	0	2	1	1	1
NC&StL	0	24	36	50	80	11	72	19	6	298	15	0	0
StL - SF	0	8	9	12	8	13	3	9	0	62	4	0	0
SAL	0	1	2	2	0	10	7	2	0	24	7	0	0
Southern	0	1	2	8	73	91	21	7	5	208	44	21	1
T&NO	0	0	0	1	1	0	0	6	6	14	4	0	0
T&P	0	0	0	0	1	0	2	0	0	3	0	0	0
TOTAL	0	295	108	240	192	155	717	127	33	1867	407	77	14
ALL MILLS	76	10641	963	1130	1760	872	9751	1215	1219	27627	6734	1436	385

TABLE 8
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1954
ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and after				Joints Inspected With Defect Detecting Instruments
	Detected Failures		Service Failures		Detected Failures		Service Failures		
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	
AT&SF	34	20	16	4	78	112	32	8	1,539,556
ACL	59	250	3	46	164	274	2	8	140,000
B&O	76*	0	1409	95	7*	1*	48	19	-
B&OCT	0	1	7	15	0	0	0	1	15,200
Ban & Aroos	0	0	2	0	0	0	1	0	-
B&LE	0	0	0	0	0	0	0	0	-
B&M	19	15	24	1	2	1	1	0	352,681
CP	0	0	55	5	0	0	112	12	-
C of Ga	0	0	0	0	0	0	1	2	-
C&O - Ches	0	0	24	20	0	0	4	18	4,150
C&O - PM	0	0	2	0	0	0	1	0	-
CB&Q	4*	0	56	15	3*	1*	15	5	-
C&EI	0	0	11	0	0	0	34	0	-
CI&L	83	13	45	3	4	0	1	23	32,200
CMStP&P	241	21	424	93	0	0	9	9	263,800
C&NW	31	14	460	32	1	31	94	17	28,600
CRI&P	12*	10*	58	118	8*	2*	52	198	-
C&S	0	0	1	0	0	0	0	0	-
D&H	0	0	12	2	0	0	1	3	20,684
DL&W	-	-	-	-	-	-	-	-	-
D&RGW	0	0	10	19	0	0	3	13	-
Erie	6	29	2	3	4	29	2	1	7,529
GTW	15	56	18	1	11	7	20	0	26,774
GN	8	0	120	0	0	0	41	0	640
IC	38*	6*	33	8	9*	8*	24	21	-
JCL	63	10	30	8	45	4	6	0	9,157
KCS	0	0	1	0	0	0	0	0	-
L&HR	0	0	14	0	0	0	1	0	-
L&NE	0	0	7	2	0	0	0	0	-
LV	0	0	47	0	0	0	3	0	-

TABLE 8 (Cont.)
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1954
ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and after				Joints Inspected With Defect Detecting Instruments
	Detected Failures		Service Failures		Detected Failures		Service Failures		
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	
LI	0	0	8	3	1*	0	0	0	-
L&N	247	725	35	0	162	80	44	0	500,000
Me Cen	-	-	-	-	-	-	-	-	-
MStP&SSM	0	47	0	65	0	0	0	0	134
MKT	0	0	0	0	0	0	2	0	-
MP Lines	4	3	11	28	1057	149	28	45	39,383
NC&StL	0	1*	0	1	0	0	2	6	-
NYC - East	50*	5*	82	25	22*	18*	170	19	-
NYC - West	36**	54**	195	118	155**	47**	130	61	19,480
NYC&StL	21	3	23	2	109	4	182	1	130
NYNH&H	115	66	144	11	68	96	20	27	107,780
N&W	0	25	1	2	0	18	4	0	10,482
NP	7*	15*	608	417	3*	1*	90	334	-
PRR	938	224	1495	220	641	402	303	95	795,642
P&LE	0	0	0	0	30	51	6	0	173,911
Reading	8*	0	1	0	0	0	0	0	1,736***
RF&P	-	-	-	-	0	191	2	0	3,890
StL - SF	-	-	-	-	-	-	-	-	-
SAL	0	0	12	3	0	0	18	4	-
Southern	47	610	0	0	7	40	0	0	74,002
SP	0	25	2	6	6	150	12	11	154,300
T&NO	0	23	0	0	0	6	0	0	19,522
T&P	103	71	11	2	35	37	8	7	113,018
UP	125	36	2	1	222	84	14	2	1,240,000
Virginian	0	0	1	1	0	0	0	0	134,979
W Md	0	0	0	0	0	0	1	1	-
Totals	2390	2378	5527	1395	2854	1844	1544	971	5,829,360

* Found by visual inspection
** Found partially by visual inspection and partially by audigage
*** Indicates partial total, actual total unknown due to lack of information.

TABLE 9 - ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, BY ROAD, MILL AND YEAR ROLLED TO OCTOBER 1, 1955

Roads	Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	Total
CP	Algoma					1 (b)	1 (a)	1 (b)			1 (a)		2 (b)	1 (a)	1 (b)	2 (b)			10
Mich. C	Algoma					1 (b)			1 (b)										2
PM	Algoma						1 (a)												1
NYNH&H	Carnegie (ET)			1 (c)															1
N&W	Carnegie (ET)					1 (a)				1 (c)									2
AT&SF	Colorado					1 (c)													1
CN	Dominion						1 (b)												1
C&NW	Gary		3 (b)	2 (b)															5
CB&Q	Gary		3 (b)																3
GN	Gary		1 (b)																1
NYC	Gary				1 (b)														1
Wabash	Gary			1 (b)															1
AT&SF	Inland							2 (a)											2
CB&Q	Inland									1 (a)	3 (a)								4
C&O	Inland	1 (a)	3	3 (a)	3			6 (a)			1 (a)	1 (a)						1 (a)	19
CMStP&P	Inland										2 (a)								2
CRI&P	Inland												1 (a)						1
UP	Inland					3 (a)	3 (a)												6
B&M	Lackawanna										1 (a)								1
C&O	Lackawanna															1 (a)			1
LV	Lackawanna								3 (a)	1 (a)									4
NYC	Lackawanna								1 (a)	1 (a)	2 (a)								4
NYC&StL	Lackawanna								2 (a)		3 (a)			3 (a)	1 (a)				9
AT&SF	Steelton			3 (a)															3
B&O	Steelton						1 (a)	1 (a)	2 (a)	1 (a)	1 (a)	1 (a)	1 (a)		1 (a)		1 (a)	1 (a)	11
B&M	Steelton						2 (a)		1 (a)										3
C of NJ	Steelton									1 (a)									1
C&O	Steelton	5 (a)		1 (a)	4 (a)		3 (a)						1 (a)			1 (a)			15
D&H	Steelton				1 (a)	2 (a)	1 (c)		1 (a)	1 (a)									6
MP	Steelton			1 (a)															1
N&W	Steelton					1 (a)	3 (a)		7 (a)					1 (a)			1 (a)		13
NYNH&H	Steelton			3 (a)		2 (a)	1 (a)		1 (a)	2 (a)									9
PRR	Steelton		2 (a)																2
RF&P	Steelton			1 (a)			1 (a)								2 (a)				4
SAL	Steelton							2 (a)		1 (a)									3
So Ry	Steelton							1 (a)		2 (a)									3
SP	Steelton		18 (a)	3 (a)	6 (a)	5 (a)	1 (a)												33
T&NO	Steelton		2 (a)	1 (a)															3
Va.	Steelton						2 (a)	1 (a)	1 (a)										4
C of GA.	Tennessee									1 (c)									1
L&N	Tennessee							1 (c)											1
SP	Tennessee		1 (b)																1
TOTAL		6	33	20	15	17	21	15	20	13	14	2	5	5	5	4	2	2	199

TABLE 9 (Cont). - SUMMARY BY MILLS

Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	Total
Algoma					2	2	1	1		1		2	1	1	2			13
Carnegie (ET)			1		1				1									3
Colorado	*				1													1
Dominion						1												1
Gary		7	3	1														11
Inland	1	3	3	3	3	3	8		1	6	1	1					1	34
Lackawanna								6	2	6			3	1	1			19
Steelton	5	22	13	11	10	15	5	13	8	1	1	2	1	3	1	2	1	114
Tennessee		1					1		1									3
TOTAL	6	33	20	15	17	21	15	20	13	14	2	5	5	5	4	2	2	199

Note: (a) TRANSVERSE FISSURE from hot torn steel. (b) TRANSVERSE FISSURE from shatter cracks due to improper cooling (c) TRANSVERSE FISSURE from inclusion. Summary - 22 T. F.'s from shatter cracks, 6 T. F.'s from inclusions, 171 T. F.'s from hot torn steel.

* No cc rail rolled.

System had not reported 1128 failures within the joint bar limits for 1954, as compared to 7 failures in 1953. These represent more than 10 percent of all this type of failures reported in Table 6.

These occasional large annual increases of the failures within the joint bar limits can be traced to the increased use of supersonic devices for detecting bolt hole and rail end fillet cracks. Table 8 was added last year to give data on service and detected failures of this type. This table shows the number of failures found in 1954 in rail of 100 lb per yard or over, separated between that rolled prior and subsequent to 1937. The data are also shown separately for service and detected failures, and for bolt hole and other web cracks. To this table has been added this year a column giving the number of joints inspected with defect detecting instruments. It will be noted that most roads used these instruments to some extent in 1954. The number of detected failures within joint bar limits for rail rolled in 1937 and after was 4698 in 1954, compared to 5611 in 1953; the number of service failures was 2515 in 1954, compared to 2438 in 1953.

The principal remaining rail problem is the increasing number of rail failures from detail fractures due to shelling, and research is being actively progressed to find a practical solution.

All failures in control-cooled rail that are thought to be transverse fissures are sent to the University of Illinois for verification by Professor R. E. Cramer as a part of the cooperative Rail Failure Investigation sponsored jointly by the AAR and the AISI. Table 9 has been prepared by Professor Cramer to show the results to date of his examination of such rails. It will be noted that most of the failed rails sent to him were found to be transverse fissures from hot torn steel (a condition found to result from reheating blooms to too high a temperature). No transverse fissures from improper control cooling has been reported in rail rolled in United States mills since 1939, a very remarkable record.

Report on Assignment 4

Rail End Batter: Causes and Remedies

K. K. Kessler (chairman, subcommittee), E. L. Anderson, B. Blowers, B. Bristow, R. M. Brown, B. Chappell, C. J. Code, L. S. Crane, W. J. Cruse, J. K. Gloster, R. L. Groover, J. C. Jacobs, L. R. Lamport, C. C. Lathey, H. S. Loeffler, B. R. Meyers, E. E. Oviatt, G. L. P. Plow, W. G. Powrie, R. B. Rhode, J. G. Roney, G. L. Smith, A. P. Talbot, R. P. Winton, J. E. Yewell.

This is a progress report, presented as information.

The investigation, as was outlined in the AREA Proceedings, Vol. 56, 1955, page 926, is in progress. One rolling-load machine has been in operation on this work continuously during 1955 at the Research Center. Seven rail joints have been subjected to 5,000,000 cycles each at 30,000-lb load. A metallurgical investigation on each of these joints is now in progress.

Report on Assignment 5

Economic Value of Various Sizes of Rail

J. C. Jacobs (chairman, subcommittee), E. L. Anderson, B. Blowers, B. Chappel, L. S. Crane, G. H. Echols, P. O. Ferris, W. H. Hobbs, N. W. Kopp, W. B. Leaf, H. S. Loeffler, B. R. Meyers, E. Osland, R. E. Patterson, R. B. Rhode, J. G. Roney, J. F. Shaffer, A. A. Shillander, W. D. Simpson, J. S. Wearn.

Your committee submits the following report of progress as information. It is a continuation of Study A reflecting changes in the test mileage and computed to show averages after 11 years. The labor and material averages are computed to compensate for the decrease in test track mileage.

Study A

Result of Study of Illinois Central Railroad, Northward Track, Mattoon to Savoy, Ill., Test Sections of 112-Lb and 131-Lb Rail

112-Lb Rail

MP 152.24–172.00 laid in 1942 and 1943
Original test included:
- 19.76 track miles
- 18 turnouts
- 1 railroad crossing
- 22 public road crossings
- 2 private grade crossings
- 24 in joint bars

Changes in rail mileage.
- 1950—M.P. 152.09–152.24, laid in 115 lb—0.15 miles—added to test.
- 1952—M.P. 155.87–160.52, relayed in 132 lb—4.65 miles—dropped from test.
- 1953—M.P. 160.52–163.55, relayed in 132 lb–3.03 miles—dropped from test.
- 1954—M.P. 152.09–155.87, relayed in 132 lb—3.78 miles—dropped from test.

131-Lb Rail

M.P. 132.00–154.24 laid in 1944
Original test included:
- 20.24 track miles
- 21 turnouts
- 3 railroad crossings
- 22 public road crossings
- 6 private grade crossings
- 36-in joint bars

Changes in rail mileage.
- 1950—M.P. 152.09–152.24 laid in 115 lb—0.15 miles — dropped from test.

Comparison of the Two Sections Cost of Investment—1944 Prices

Average Annual Traffic Density—28,000,000 gross tons

Item	*Investment Charges per Mile*	
	112-Lb	*131-Lb*
Gross cost—rail and other track material	$12,643	$14,413
Less estimated salvage	Cr. 4,284	Cr. 5,011
Net cost—rail and other track material	$ 8,359	$ 9,402
Labor cost to lay	1,338	1,473
Total Cost	$ 9,697	$10,875
Estimated life—based on 1955 condition	*14 Years*	*20 Years*
Annual cost—Rail and other track material	$ 597	$ 470
Labor to lay	96	74
Interest at 6 percent*	839	953
Total annual investment cost	$ 1,532	$ 1,497

*On gross outlay for material and labor.

MAINTENANCE LABOR AND MATERIAL PER MILE

112-Lb					131-Lb				
Year	Miles Maintained	Man-Hours	Cross Ties	Cu Yd Ballast	Year	Miles Maintained	Man-Hours	Cross Ties	Cu Yd Ballast
1943	19.76	2,480	716	628	1944	20.24	2,606	1,065	647
1944	19.76	413	5	17	1945	20.24	131	-------	30
1945	19.76	701	236	251	1946	20.24	370	5	114
1946	19.76	1,166	416	579	1947	20.24	748	172	301
1947	19.76	645	208	273	1948	20.24	245	38	185
1948	19.76	1,005	186	294	1949	20.24	670	10	116
1949	19.76	1,574	541	423	1950	20.09	1,642	402	323
1950	19.91	694	174	159	1951	20.09	614	59	52
1951	19.91	667	48	193	1952	20.09	1,144	62	304
1952	15.26	748	30	140	1953	20.09	1,089	139	120
1953	12.23	1,110	91	292	1954	20.09	392	-------	21
Total 11 years		11,203	2,651	3,249			9,651	1,952	2,213

AVERAGE OF ELEVEN YEARS

	112 Lb		131 Lb		Savings By Use of 131 Lb	
	Charge	Percent	Charge	Percent	Charge	Percent
Man-hours	1,018		877		141	
Cost at $1.10*	$1,120	53	$ 965	57	$ 155	35
Cross ties	241		177		64	
Cost at $2.94*	$ 709	33	$ 520	31	$ 189	43
Ballast (stone and slag) Cu Yd	295		201		94	
Cost at $1.00*	$ 295	14	$ 201	12	$ 94	22
Total maintenance	$2,124		$1,686		$ 438	
Percent		100		100		100
Investment charges	$1,532		$1,497		$ 35	
Total cost	$3,656		$3,183		$ 473	
Percent					12.9	

*Average prices 1943–1954.

Summary

The 131-lb rail is in better condition than the 112-lb rail in regard to wear and joint condition.

The original estimate of service life in first location was 15 years for the 112-lb and 25 years for the 131lb. However, it now appears that 14 years for the 112-lb and 20 years for the 131-lb will be more nearly accurate, and computations have been revised accordingly.

Much of the 112-lb rail has been removed due to bolt hole failures where joint packing was used. Joint packing was not used on the 131-lb rail. Additional 112-lb rail has been replaced with 132-lb rail to improve riding condition at high speeds. Only 8.45 miles of the original 19.76 miles of 112-lb rail remain in track after 1954.

All the original 131-lb rail, except 0.15 miles removed to provide emergency rail, is still in service.

The greatest savings realized through use of the 131-lb rail has been in cross ties, possibly due to the use of long and heavier joint bars, larger tie plates, and greater rail rigidity. Cross ties in both sections are renewed in accordance with similar maintenance standards and conditions.

Report on Assignment 6

Service Tests of Various Types of Joint Bars

T. A. Blair (chairman, subcommittee), B. Chappell, C. J. Code, L. S. Crane, J. C. DeJarnette, P. O. Ferris, E. B. Fields, R. L. Groover, J. C. Jacobs, K. K. Kessler, N. W. Kopp, W. B. Leaf, H. S. Loeffler, E. H. McGovern, B. R. Meyers, E. Osland, G. L. P. Plow, E. F. Salisbury, J. F. Shaffer, S. H. Shepley, G. L. Smith, J. S. Wearn, R. P. Winton

No measurements were made of joints in test sections this year, as it was decided that measurements to be made next year would fulfill our requirements.

Report on Assignment 7

Joint Bar Wear and Failures; Revision of Design and Specifications For New Bars, Including Insulated Joints and Bars For Maintenance Repairs

Embert Osland (chairman, subcommittee), T. A. Blair, Blair Blowers, R. M. Brown, L. S. Crane, J. C. DeJarnette, E. B. Fields, J. L. Gressitt, R. L. Groover, W. H. Hobbs, S. R. Hursh, L. R. Lamport, E. H. McGovern, B. R. Meyers, G. L. P. Plow, J. F. Shaffer, S. H. Shepley, H. F. Whitmore.

This is a progress report, submitted as information.

The principal work of the assignment during the past year has been the rolling-load tests of joint bars being conducted at the University of Illinois, under the direction of Professor R. S. Jensen. This year the rolling-load tests were extended to include compromise joints, with the view of determining whether any improvements could be suggested in present designs and whether or not there were any outstanding differences in forged or cast bars The results of these tests are submitted in Appendix 7-a.

Bars which failed to meet the physical requirements of the specifications, as a general rule, were the first to fail in the rolling-load machines, and the majority of bars which have failed in service, when tested in the laboratory, have also shown physical properties below that required by the specifications. A graph showing cycles for failure indicates that the results correspond quite well to a straight line extending from 100,000 cycles at 170 surface Brinell, to 1,000,000 cycles at 250 surface Brinell.

Since there is a definite relationship between Brinell hardness and tensile strength, we proposed to representatives of the steel mills at the Joint Contact Committee meeting in Williamsburg, Va., that a number of Brinell hardness tests be substituted for a portion of the tensile strength tests now required by the specification, and also suggested that some thought be given to the installation of radiation pyrometers just ahead of the quenching baths. This matter will be given consideration by the steel companies and a report will be rendered next year.

Appendix 7–a

Fourteenth Progress Report of the Rolling-Load Tests of Joint Bars

By R. S. Jensen
Assistant Professor of Theoretical and Applied Mechanics, University of Illinois

Introduction and Acknowledgment

This report covers tests of joint bars conducted during the past year in the Talbot Laboratory, University of Illinois, as a part of the work of the Engineering Experiment Station in cooperation with the American Railway Engineering Association Committee on Rail, under Assignment 7—Joint Bar Wear and Failures; Revision of Design and Specifications for New Bars and Bars for Maintenance Repairs. Embert Osland, office engineer, Atchison, Topeka and Santa Fe Railway, is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads.

Acknowledgment is made of the services of James Bryant and Elmer Hunt, mechanicians in the Talbot Laboratory shops.

Testing Machines and Test Specimens

Joint bar tests were made in three 33-in stroke rolling machines similar to the one described in the AREA Proceeding, Vol. 40, 1939, page 649. The dimensions of the test joint and method of loading are described in the Proceedings, Vol. 44, 1943, page 587. In all tests, the maximum bar bending stresses are obtained with the wheel load at the joint gap, and are 50 percent in value and reversed in sign with the wheel load at the cantilever end of the stroke. The criterion for bar failure is taken to be the number of cycles of loading to propagate a fatigue crack to one-half the bar height.

Results of Rolling-Load Tests

Rolling-load tests have been completed on 17 joints, using 36-in, headfree bars, since the last annual report was published. Eleven tests have been completed on 115 RE, headfree, 36-in bars (joints 328 to 338) on which easements 3/64 in deep and 1⅜ to 1½ in long were ground into the top center of each bar in accordance with the recommendation for head easement for joint bars in the AREA Manual. The bolt hole spacing on these bars was 7⅛ in between central holes and 6 in between remaining holes. The chemical analysis of the heat from which the bars were rolled is as follows:

Heat 8500, Serial 6, C—0.45, Mn—0.64, P—0.011, S—0.036, Si—0.11

Six tests have been completed on Rajo compromise joints, type number 106A, head free, for 132-lb to 115-lb rail sections. The bars for these 6 joints (joints 339 to 344) were cast from 2 heats with chemical compositions as follows:

Heat No.	*C*	*Mn*	*S*	*P*	*Si*	*Mo*
1–7892	0.32	1.35	0.032	0.035	0.37	0.20
1–7891	0.29	1.17	0.021	0.032	0.31	0.19

Data on these joints are tabulated in Table 1, and physical properties, as determined by tensile tests on specimens cut from each failed bar, are listed in Table 2.

TABLE 1—ROLLING-LOAD TESTS OF JOINT BARS

Maximum positive bending moment: 44,400 lb load–400,000 in-lb
Maximum negative bending moment is 50 percent of positive moment
Bolt tension: 15,000 lb. Bolts: 1 in diameter, heat treated, prestressed

Joint No.	Cycles for Failure	Bar Failure (N. = North, S. = South)	Surface Hardness Failed Bar BHN	Hardness on Tensile Specimen BHN	Depth of Decarb. from Micrograph Inches	Pinching from Hot Sawed Rails on Failed Bar Inches: Top	Pinching from Hot Sawed Rails on Failed Bar Inches: Bottom
Bars: H5 RE Headfree 36-in, Ground Easements, Serial 6, Rail Ends Milled							
328	612,800	N. Base—To bolt hole	Top 198 Base 218	223	0.013	000	0.000
329	808,300	S. Top —$\frac{7}{8}$″ from rail end	200	231	0.011	000	0.001
330	1,240,700	S. Top —$\frac{1}{2}$″ from rail end	188	231	0.004	000	0.001
331	1,398,500	S. Top —$\frac{3}{4}$″ from rail end	191	226	0.009	000	0.000
332	682,000	S. Top —$\frac{3}{4}$″ from rail end	207	229	0.008	000	0.001
333	2,000,000	No Failure	N-228 S-225	234 231	0.007 Slight	000 000	0.000 0.001
334	1,038,300	S. Base —To bolt hole	Top 218 Base 214	236	0.010	000	0.001
335	2,000,000	No Failure	N-209 S-216	215 223	0.012 0.009	000 000	0.002 0.001
336	1,005,200	N. Base—Rail end	Top 207 Base 216	212	0.010	000	0.001
337	2,000,000	No Failure	N-193 S-186	213 230	0.006 0.010	000 000	0.000 0.000
338	2,000,000	No Failure	N-222 S-224	238 214	0.013 0.005	000 000	0.000 0.000
	1,344,100	Average of 11 Joints					
Bars: Rajo Compromise Joint Type 106A—132 RE to 115 RE Rail Section Headfree, 36-in Hole Spacing 7$\frac{1}{8}$–6–6 in							
339	166,200	S. Base—6 in from rail end	221	216	0.017	000	0.000
340	298,800	N. Base—Rail end	219	212	0.018	.001	0.001
341	369,700	S. Base—To bolt hole	216	227	0.016	000	0.000
342	381,500	N. Base—2 in from rail end	217	220	0.022	000	0.003
343	124,400	S. Base—5 in from rail end	207	198	0.022	000	0.001
344	500,000	N. Base—Rail end	203	213	0.020	000	0.000
	306,760	Average for 6 joints					

TABLE 2—PHYSICAL PROPERTIES OF LABORATORY JOINT BARS

Bar Type	*Joint Number*	*Surface Hardness BHN*	*Hardness on Tensile Specimen BHN*	*Yield Point Psi*	*Tensile Strength Psi*	*Rreduction of Area Percent*	*Elongation 2-In Gage Length Percent*
115 RE HF----	328N	198	223	68,400	110,000	49.4	21.0
	329S	200	231	70,400	112,700	48.0	19.0
	330S	188	231	70,300	111,500	48.4	19.0
	331S	191	226	68,000	109,200	48.8	20.0
	332S	207	229	68,400	110,200	48.3	19.0
	333N	228	234	72,100	114,300	48.7	19.0
	333S	225	231	70.700	113,800	48.4	19.0
	334S	218	236	71,400	113,800	49.0	19.5
	335N	209	215	68,200	109,200	50.0	21.0
	335S	216	223	70,400	112,200	48.0	19.5
	336N	207	212	68,000	108,000	48.2	20.0
	337N	193	213	66,000	107,300	47.0	20.0
	337S	186	230	69,700	111,000	47.4	19.0
	338N	222	238	72,300	113,800	48.7	19.5
	338S	224	214	68,100	108,500	46.4	19.5
The following three specimens were machined from the base of the bars							
	328N	218	217	65,600	107,800	50.5	20.0
	334S	214	231	70,600	114,000	49.0	19.5
	336N	216	206	62,400	101,700	53.6	22.5
Ra'o Compromise Joint 132–115--	339S	219	225	81,300	103,500	50.2	19.0
	304N	222	217	82,400	103,300	53.3	21.0
	341S	213	216	82,400	103,500	40.5	17.0
	342N	216	220	84,000	103,500	45.0	19.5
	343S	209	207	75,800	97,000	48.4	20.0
	344N	207	212	79,800	100,000	54.1	23.0
The following six specimens were machined from the base of the bars							
	339S	221	216	77,400	95,800	Broke outside G.L.	
	340N	219	212	77,500	96,600	Broke outside G.L. (Flaw)*	
	341S	216	227	79,600	101,200	25.0	13.0
	342N	217	220	79,200	85,000	21.2	5.0*
	343S	207	198	71,500	93,700	31.7	17.5
	344N	203	213	79,400	100,000	48.8	20.5

*Small porosity visible after break.

AREA Specifications:

Tensile strength, min	100,000 psi
Yield point, min	70,000 psi
Elongation in 2 in, min	12 percent
Reduction of area, min	25 percent

Hardness Tests on Joint Bars

Both Brinell and Rockwell B hardness readings were taken on the upper and lower fishing surfaces of all bars before testing, and Brinell readings were also taken on both ends of the tensile specimens cut from the center of the head of each failed bar.

For the 115 RE, headfree bars, the Brinell readings on the top fishing surfaces ranged from 185 to 228, with an average hardness of 205; readings on the lower fishing surfaces ranged from 181 to 241, with an average hardness of 218 for 22 bars. Rockwell B readings, converted to equivalent Brinell, averaged 48 points lower for these bars.

The tensile specimens machined from the heads of the bars showed Brinell hardnesses ranging from 212 to 238, with an average hardness of 226.

For the cast compromise joint bars, Brinell readings on the top surfaces ranged from 207 to 222, with an average hardness of 213, and Brinell readings on the bottom surfaces ranged from 203 to 225, with an average hardness of 213. Rockwell B readings, converted to equivalent Brinell, averaged 32 points lower for these bars. The tensile specimens machined from the bars showed Brinell hardnesses from 198 to 227, with an average of 215.

Rolling-Load Tests of 115 RE Headfree Bars with Ground Easements

Results of 11 tests of 115 RE, headfree, 36-in bars with ground easements, are given in Table 1. The easements were ground in the laboratory on the top fishing surfaces of the bars to a depth of 3/64 in and to a length of 1⅜ to 1½ in, with a gradual taper from the maximum depth at the center out to the ends of the easement. The easements were carried over the top surfaces of the bars, well beyond the area of contact of bar and rail.

The average cycles for failure for these 11 joints was 1,344,100 cycles. This average is slightly lower than the average of 1,462,450 cycles for 12 tests of 115 RE headfree bars without easements (joints 174–185) reported in 1950, in which 5 of the joints ran to 2,000,000 cycles without failure. In the present group of tests using bars with easements, 4 of the joints ran to 2,000,000 cycles. Although the average number of cycles for the joints with easements is slightly lower than for the group without easements, it should be noted that the ground easements completely eliminated gouging by the rail ends, and the bar failures which were from the top surfaces started outside of the easements in areas of heavy bearing. For this reason it is thought that the easements would increase joint bar life in track. Fig. 1 shows three of the fractures, bars 330S and 332S, with failures from the top surface just outside the easements, and bar 334S, which cracked from the base to an oval bolt hole.

Four of the bars failed from the top surfaces in areas of heavy bearing outside of the easements, 3 bars failed from the base, and 4 joints ran to 2,000,000 cycles with

Fig. 1—Fatigue failures of 115 RE bars.

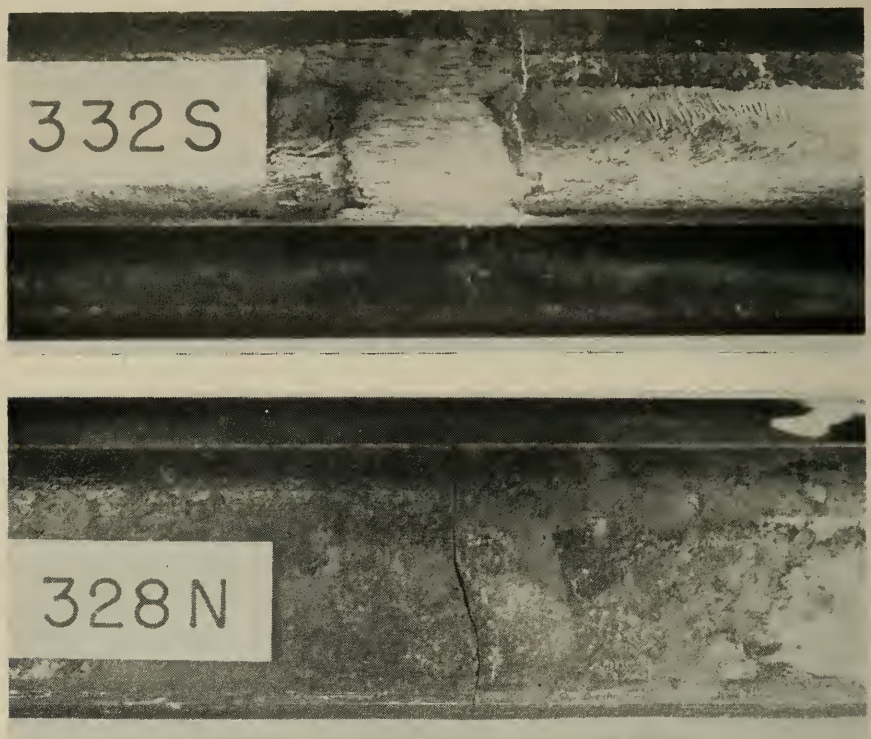


Fig. 2—Joint bar fishing surfaces with cracks.
Upper—Top fishing surface of bar 332S.
Lower—Lower fishing surface of bar 328N.

no failure. One of the base failures originated in a gouge from the rail end, while the other 2 base failures progressed to oval bolt holes. Small fatigue areas ⅛ and ¼in. in height were observed at the holes. Fig. 2 shows 2 cracks which caused failure; bar 332S in the upper figure shows the crack outlined by magnaflux just outside the easement; bar 328N in the lower figure shows the crack in an area of heavy bearing on the base of the bar.

Fig. 3 shows both bars of joint 337 after 2,000,000 cycles with no failure. Since no gouging was observed on the top surface of the bars, it seems apparent that the depth of 3/64 in for the easements was adequate.

Magnaflux examination revealed additional transverse cracks on the top fishing surfaces of all except one of the failed bars and on all of the companion bars. The cracks ranged in length from ⅛ to ½ in for the most part, with an occasional crack ¾ in. in length. The cracks occurred in heavy bearing areas within a few inches of the centers of the bars.

Micrographs were taken on specimens cut from each failed bar and revealed a fairly fine grain structure for all bars. Fig. 4 shows micrographs from three bars which are representative. Some decarburization was noted, up to depths of 0.013 in for the failed bars.

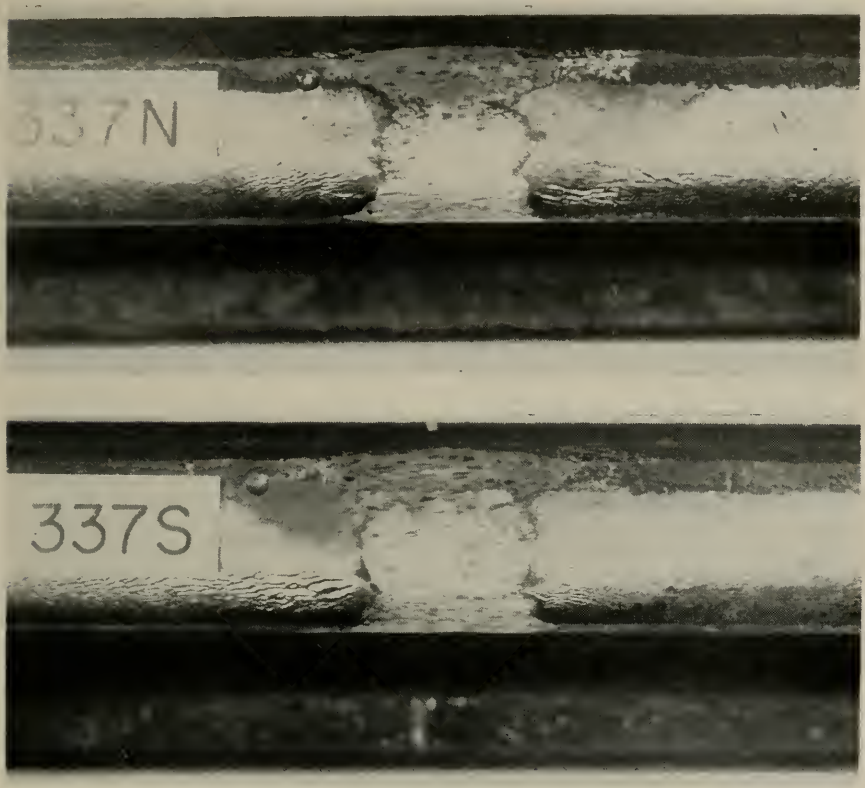


Fig. 3—Bars from joint 337 showing easements.
Top fishing surfaces after 2,000,000 cycles with no failure.

The physical properties of the bars, as listed in Table 2, are well above AREA specifications in tensile strength, while 8 of the 15 bars tested fell only slightly below the yield point specification of 70,000 psi.

Since tightening of the bolts was noted to bend the bars laterally at mid-length, lateral deflection readings were taken on upper and lower bar flanges before bolting, after bolting, and at regular intervals during the progress of each test. The amount of lateral bending varied with individual bars, and since unbroken bars recovered to their original shape upon release of bolt tension, it was apparent the bending was elastic.

Lateral deflection readings on the bars indicated that at 100,000 cycles the centers of the bars were bowed inward from 0.004 to 0.015 in, with an average of 0.006 in for the upper flanges. Bending on the lower flanges ranged from 0.008 to 0.041 in inward, with an average of 0.024 in.

Out-to-out measurements, that is the distance between outer bar flanges, indicated that at 100,000 cycles the lower flanges had moved inward an average of 0.030 in at the center of bar length and 0.005 in average at the ends of the bars. The upper flanges averaged 0.008 in movement inward at the center and less than 0.001 in at the ends.

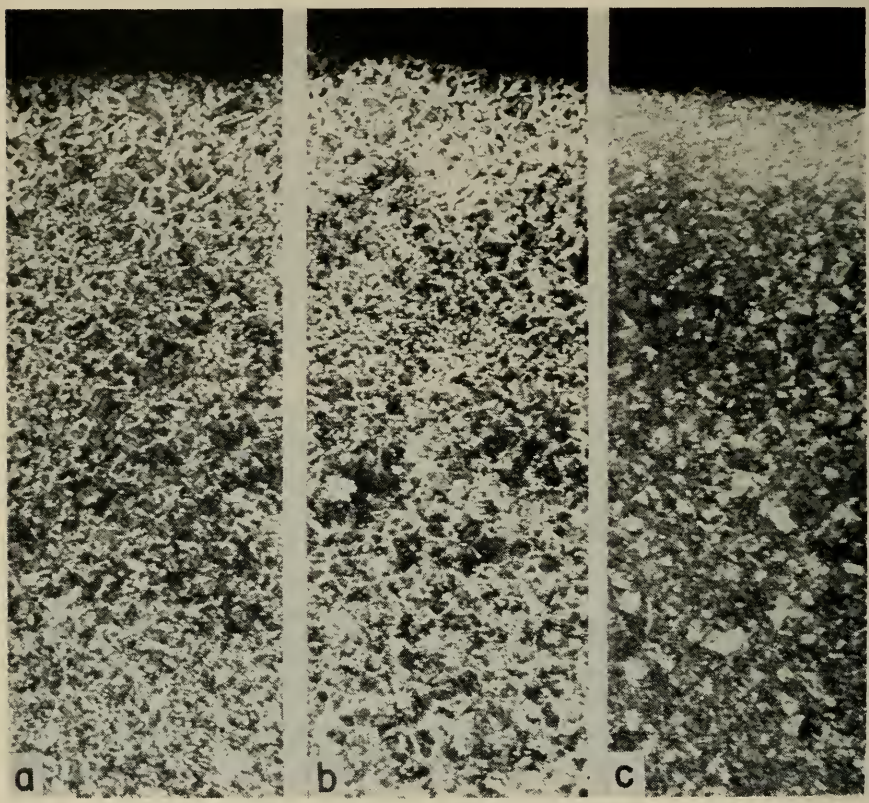


Fig. 4—Micrographs from joint bars.
a. bar 330S; b. bar 332S; c. bar 333N. About 70× magnification; 2 percent nital etch.

Rolling-Load Tests of Rajo Compromise Joints, 131–115 Lb

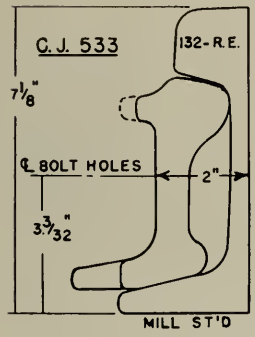
Results of 6 tests of Rajo Compromise joints, type No. 106A, headfree, 36-in bars, are listed in Table 1. The average cycles for failure for these joints is 306,760 cycles. Fig. 4A shows the drawing for this type of joint.

All of the 6 bar failures were from the base. Two failures originated at the rail end where the joint bar changes section from 115 to 132 lb. The outer 4 failures occurred from 2 to 6 in from the rail ends, either starting in the outer portion of the toe, or in heavy bearing areas, except for bar 343S, in which the fracture started in the radius of the wide base flange or long toe of the bar. The crack in bar 341S progressed upward to a round bolt hole.

Examination of the six fractures, three of which are shown in Fig. 5, revealed that four of the bars contained porosity which was visible on the fractures and undoubtedly contributed to their failure at that section. The two bars with the lowest number of cycles, bars 339S and 343S, contained porosity which extended to within a few thousandths of an inch of the surface in the outer edge of the toe of the bar. The porosity in each case acted as a stress raiser and was the origin of the crack which caused failure.

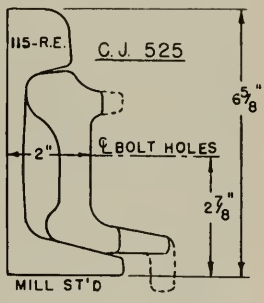
THE RAIL JOINT COMPANY

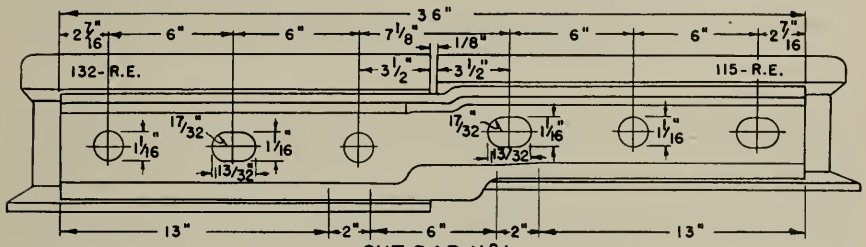
RAJO COMPROMISE JOINT TYPE NO 106 A HEADFREE



4-PIECE
INT. PAT'S T-70

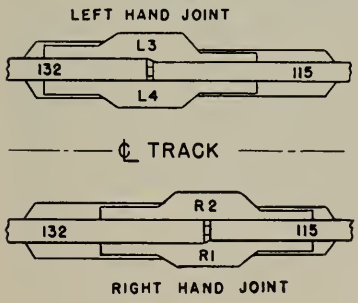
HOLES
132 R.E. END USE Y-4 MARK 219-0
115 R. E. END USE Y-4 MARK 219-0





OUT BAR Nº 1

MIDDLE REINFORCEMENT PER DATA Nº 120



CHESAPEAKE & OHIO RY. CO.

FILE No. 36-566
NOV. 24, 1950 ISSUE NO. 1

FIG. 4A—RAJO COMPROMISE JOINT

Fig. 5—Fractures of compromise joint bars.

Easements approximately $\frac{1}{16}$ in deep over the central 1¼ in of the top surface were responsible for eliminating the gouging by the rail ends. Fig. 6 shows two of the sections of the bars containing cracks from the base which caused failure. The easements are visible in the photographs. Magnaflux examination revealed no additional cracks on the failed bars and only two small cracks in a heavy bearing area on the top of one companion bar.

Micrographs for these bars revealed a fine grain structure. Three of the micrographs are shown in Fig. 7. The physical properties, as determined by tensile tests on specimens cut from the heads of the failed bars, met the AREA specifications, except for one specimen which had a tensile strength below 100,000 psi. For the specimens cut from the base of the bars, four of the specimens fell below the 100,000 psi tensile strength requirement. Small porosities were visible on two of the specimens after fracture and undoubtedly contributed to lowering their tensile strength.

Failed Bars From Service

Twenty-one pieces of failed bars from service have been received for examination and testing. All were 132 RE, 36-in, headfree bars and had failed from the top surface at the rail end. Twenty of the bars were from 1949 rollings of one mill, while the other bar was from a 1950 rolling from another mill. Brinell hardness measurements were taken on each bar after removing $\frac{1}{16}$ in of surface metal. A tensile specimen was cut from each bar, and the data on hardness and physical properties for these bars are listed in Table 3. Thirteen of the 21 specimens tested failed to meet the yield point requirement of 70,000 psi, and 6 of the specimens failed to meet the 100,000 psi tensile strength requirement. Brinell hardness readings near the surface ranged from 176 to 297, while Brinells on the tensile specimens ranged from 162 to 257.

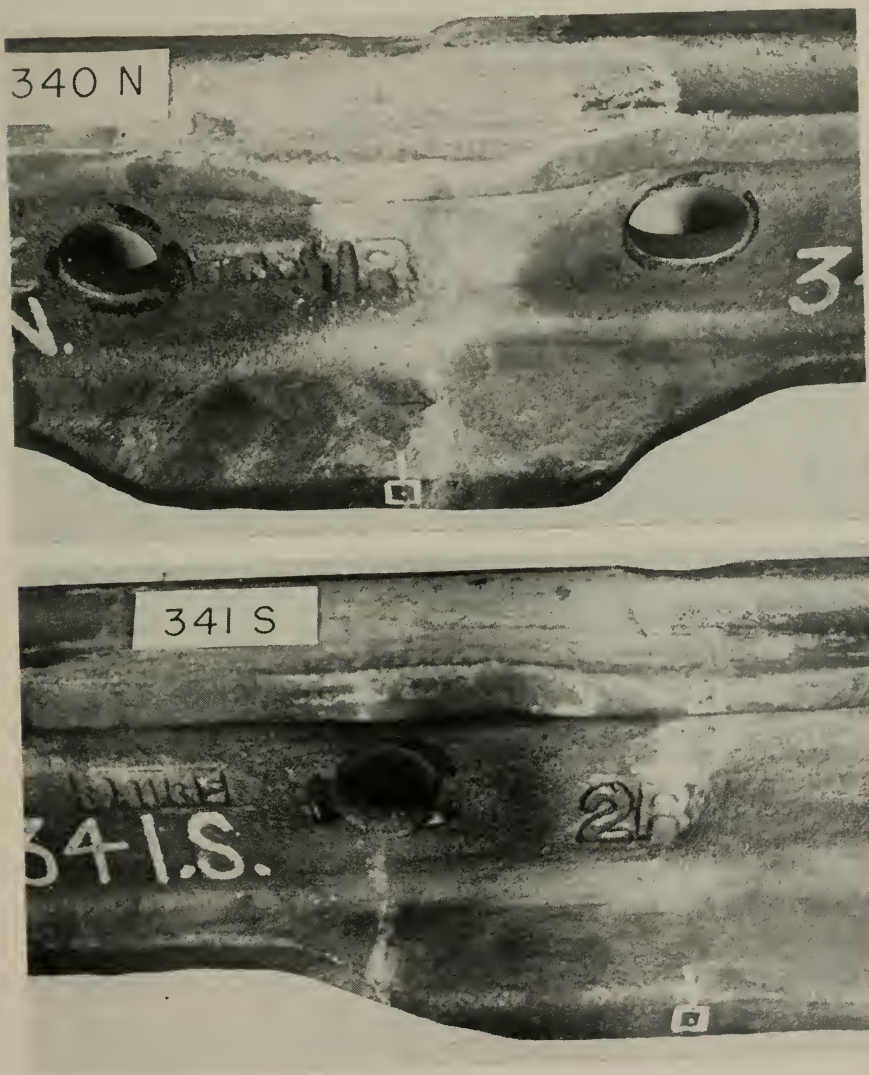


Fig. 6—Compromise joint bars showing cracks which caused failure.

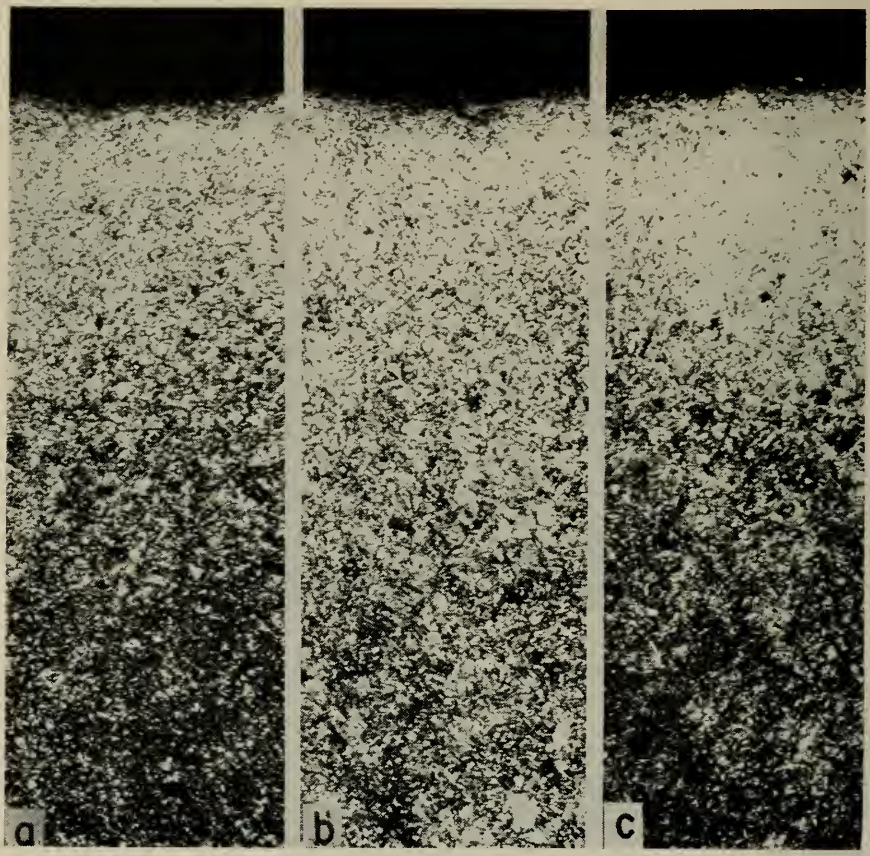


Fig. 7—Micrographs from joint bars.
a. bar 339S; b. bar 340N; c. bar 341S. About 70× magnification; 2 percent nital etch.

Micrographs were taken on specimens for each failed bar and, in general, revealed a fine grain structure for bars above 200 Brinell and a coarse grain structure for bars below 200 Brinell. Fig. 8 shows micrographs from three of the bars.

Future Work

Rolling-load tests are planned on two more types of compromise joints, 132-lb to 115-lb rail section, as follows:

6 from the Du-Wel Steel Products Company
6 forged step joints from the Youngstown mill of the U. S. Steel Corp.

Three joints from each company will be lefthand and three righthand. They will be for 1-in bolts with standard AREA drilling.

In addition, a series of fatigue tests using small specimens cut from joint bars is planned: one group of specimens from bars of low Brinell hardness (below 200) with

Table 3—Brinells and Physical Properties of Failed Bars from Service

Lab. No.	*Bar Type*	*Year Rolled*	*Hardness Near Top Surface B H N*	*Hardness on Tensile Specimen B H N*	*Yield Point Psi*	*Tensile Strength Psi*	*Reduction of Area Percent*	*Elongation 2 in Gage Length Percent*
T1	132 RE	1950	240	207	63,000	100,200	53.2	24.0
T2	132 RE	1949	218	185	49,400	93,800	43.8	22.0
T3	132 RE	1949	254	238	70,700	114,000	45.8	19.0
T4	132 RE	1949	250	238	71,900	113,200	49.8	19.0
T5	132 RE	1949	244	235	69,500	113,800	45.5	18.0
T6	132 RE	1949	271	235	75,100	117,800	47.4	18.0
T7	132 RE	1949	251	229	68,600	111,600	45.8	18.0
T8	132 RE	1949	249	238	67,700	112,800	45.2	18.0
T9	132 RE	1949	297	257	79,100	125,200	44.8	16.5
T10	132 RE	1949	172	174	44,300	89,500	43.9	22.5
T11	132 RE	1949	279	272	78,200	127,200	40.8	16.0
T12	132 RE	1949	238	189	52,700	98,000	44.8	22.0
T13	132 RE	1949	269	240	72,700	114,800	47.5	19.0
T14	132 RE	1949	268	228	62,800	107,200	46.8	18.0
T15	132 RE	1949	263	257	75,300	121,000	45.8	17.5
T16	132 RE	1949	295	243	71,000	115,000	44.1	17.0
T17	132 RE	1949	264	231	68,800*	113,800	41.5	17.0
T18	132 RE	1949	210	195	52,000	99,800	41.5	20.0
T19	132 RE	1949	233	223	69,500	111,000	49.6	21.0
T20	132 RE	1949	180	176	43,000	86,500	46.4	22.5
T21	132 RE	1949	176	162	43,500	83,800	46.0	25.0

*Yield Strength—No well-defined yield point.

AREA Specifications:

Tensile strength, min	100,000 psi
Yield point, min	70,000 psi
Elongation in 2 in, min	12 percent
Reduction of area, min	25 percent

as-rolled surfaces, and a companion group of similar hardness with machined surfaces; a second group of specimens of average hardness (200 to 225 Brinell) with as-rolled surfaces, and a companion group with machined surfaces; and a third group of specimens above 250 Brinell with as-rolled surfaces, and a companion group with machined surfaces. The specimens are to be tested in completely reversed bending stress.

Summary

1. Eleven tests of 115 RE, headfree, 36-in bars with ground easements 3/64 in. in depth and 1⅜ to 1½ in. in length averaged 1,344,100 cycles. Four of the joints ran to 2,000,000 cycles with no failure.

2. The ground easements 3/64 in. in depth were adequate to eliminate completely gouging of the bars by the rail ends. On the four bars which failed from the top surface, the cracks started outside of the easements.

3. Micrographs on specimens cut from the bars revealed a fairly fine grain structure for all bars.

4. Six tests of cast Rajo compromise joints, type 106A, 132-lb to 115-lb rail section, gave an average of 306,760 cycles. All of the bars failed from the base, with small porosity visible on four of the fractures.

5. Examination and tests of 21 bars of 132 RE section which failed in service indicated that yield points for 13 bars were below AREA specifications and that Brinells on the tensile specimens were in general lower than near the surface. All of the bars had failed from the top surface at a gouge mark caused by a rail end.

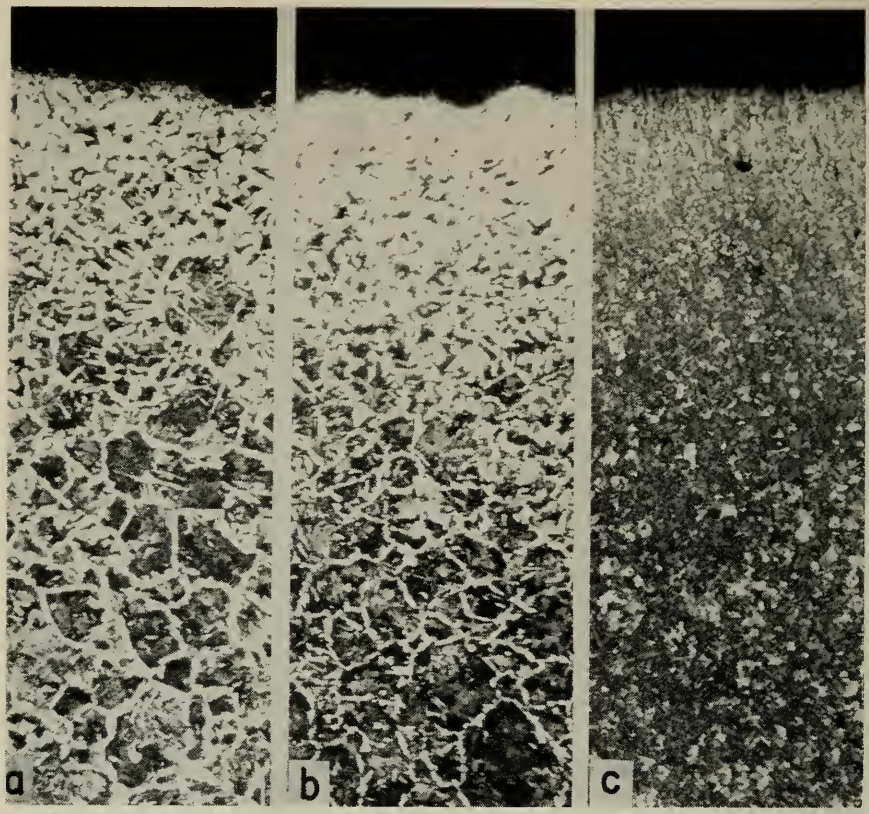


Fig. 8—Micrographs from joint bars which failed in service.
a. bar T2; b. bar T12; c. bar T9. About 70× magnification; 2 percent nital etch.

Report on Assignment 8

Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention

L. S. Crane (chairman, subcommittee), W. D. Almy, F. W. Biltz, T. A. Blair, B. Bristow, C. J. Code, W. J. Cruse, J. C. DeJarnette, J. L. Gressitt, S. R. Hursh, K. K. Kessler, C. C. Lathey, W. B. Leaf, R. McBrian, E. H. McGovern, B. R. Meyers, L. T. Nuckols, R. E. Patterson, W. C. Perkins, J. G. Roney, W. D. Simpson, J. S. Wearn, E. Wise, J. E. Yewell.

This is a progress report, presented as information.

This investigation is conducted by three task groups. The work of Group 1 is handled directly by the subcommittee; that of Group 2 by the research staff, Engineering Division, AAR; and that of Group 3 by the University of Illinois. The AAR and the AISI jointly provide funds to support the work of Group 3.

A small administrative committee comprised of members selected by the AAR subcommittee and the rail manufacturers has met regularly during the past year for the purpose of reviewing and guiding the conduct of the research work.

During the past year emphasis has been placed on following the performance of the various service installations. These investigations have continued to confirm the fact that the gage corner design improvements made on the 115, 132 and 133 RE sections have assisted in preventing the onset of shelling. They have also confirmed that where heat-treated or alloy-steel rail can be justified economically, these higher strength steels are effective in extending the service interval before gage corner shelling will occur in track. It will be noted from the accompanying tabulation that several installations of high-silicon rail steel have been made. These have not been in service for a sufficient period of time to indicate whether definite benefit will be derived from their use.

Report on Inspections of Service Tests of Heat-Treated and Alloy Rails in Shelly Territory Installations

By Research Staff, Engineering Division, AAR

In cooperation with representatives of the various rail producers and representatives of the involved railroads, a number of service test installations of heat-treated, chrome-vanadium, and high-silicon rails were inspected. These installations are on curves with a high incidence of rail failures due to shelling. Photographs, rail contours and detailed records of the observed progress of the head checks, light, medium and heavy flaking, and the shelly spots were obtained at various stages in the service life of the rails. The majority of the installations show a considerable improvement in extending the service life and in resistance to shelling.

A brief description and summary of the observations of each test installation inspected, and a progress report of the service test on the Great Northern Railroad, are presented in the following.

Denver and Rio Grande Western Railroad Service Test of 133 RE High-Silicon Rails

This test was installed in May 1951 in curves at two different locations. The curve at M.P. 351 in Glenwood Canyon is 9 deg 8 min, with 3 in elevation and an authorized maximum speed of 20 mph for freight and 40 mph for passenger trains. The curves at M.P. 366 to 366.6 at Funston are 4 deg 5 min and 5 deg 4 min, with 4 in elevation and an authorized maximum speed of 40 mph for freight and 60 mph for passenger trains.

The test in Glenwood Canyon was installed primarily to investigate the abrasion resistance of the high-silicon rail, while on the curve at Funston shelling had been experienced on standard control-cooled rail. Rails from two heats with a high silicon analysis were laid alternately with standard control-cooled rails, both on the high and the low sides of the curves.

At the time of the 1955 inspection approximately 88,000,000 gross tons of traffic had passed over these curves. The installation in Glenwood Canyon showed a considerably greater amount of curve wear in the standard control-cooled rail, as well as a considerably larger amount of head flow on the low rails of the standard control-cooled rails. No evidence of any gage corner defects associated with shelling could be noted on the control-cooled or high-silicon rails.

LIST OF ALLOY & HEAT TREATED RAIL INSTALLATIONS SINCE JANUARY 1949

Railroad	Rail Section	Type Rails Mill	Heat No.	ANALYSIS C	Mn	P	S	Si	Cr	Va	Date Installed	Place Installed	Degree Curvature	Amount of Rails
PRR	155 PS	Heat Treated-Steelton	88507	0.75	0.82	0.011	0.029	0.17	-	-	January 1949	Forge, Pa.	6° Curve	6 Rails
			82510	0.76	0.90	0.017	0.035	0.16	-	-				6 Rails
C & O	132 RE	" " "	87581	0.77	0.83	0.015	0.037	0.15	-	-	May 1949	Martha, W. Va.	3° 6' Curve	8 Rails
			82589	0.78	0.79	0.023	0.034	0.17	-	-				4 Rails
N & W	132 RE	" " "	87581	0.77	0.83	0.015	0.037	0.15	-	-	May 1949	Kermit, W. Va.	6° Curve	15 Rails
			82589	0.78	0.79	0.023	0.034	0.17	-	-				8 Rails
NYC	127 DY	Heat Treated	10440	0.72	0.78	0.020	0.036	0.17	-	-				
		(Lackawanna Rails)	25435	0.72	0.81	0.011	0.025	0.18	-	-	July 1950	Cedar Run, Pa.	7° 51' Curve	4 Rails
		(Treated at Steelton)	29436	0.71	0.85	0.014	0.031	0.19	-	-				
		Alloy - Gary	201457	0.79	1.40	0.013	0.029	0.25	0.95	0.15	July 1950	Cedar Run, Pa.	7° 51' Curve	11 Rails
N & W	132 RE	Alloy - Gary	933883	0.74	1.30	-	-	0.25	0.90	0.12	December 1950	Sciota Division	Two 6° Curves	1 Heat
G. N.	115 RE	Heat Treated-Steelton	89521	0.76	0.86	0.014	0.037	0.19	-	-	February 1951	Carlton, Minn.	4° Curve	88 Rails
DRG & W	133 RE	High Silicon-CF & I	3181	0.79	0.93	0.034	0.033	0.55	-	-	May 1951	Glenwood Canyon	9° 8' Curve	2 Heats
			8202	0.77	0.82	0.031	0.027	0.48	-	-		Out of Glenwood Canyon	4° 9' "	
													5° 4' "	
PRR	155 PS	High Silicon-Steelton	86594	0.79	0.72	0.010	0.034	0.59	-	-	October 1953	Lewistown, Pa.	2° 37' Curve	1 Heat
PRR	140 PS	Alloy - Gary	996080	0.69	1.38	0.017	0.022	0.30	1.11	0.13	October 1955	Torrance, Pa.	2-1/2° "	47 Rails
N & W	140 PS	Alloy - Gary	996080	0.69	1.38	0.017	0.022	0.30	1.11	0.13	November 1953	Webb, W.Va. Sciota Div.	6° Curve	64 Rails
DM & IR	115 RE	Alloy - Gary	976186	0.64	1.51	0.018	0.027	0.41	1.11	0.16	March 1954	Proctor Hill, Minn.	4° "	21 Rails
													2° "	52 "
												Two Harbors, Minn.	6° "	27 "
													4° "	30 "
G. N.	115 RE	Heat Treated-Steelton	90005	0.74	0.73	0.02	0.03	0.18	-	-	April 1954	Mesabi Division	7° Curves 3° to 7° 36'	166 Rails
U.P.	133 RE	High Silicon-CF & I	2694	0.69	0.84	0.024	0.022	0.57	-	-	April 1954	Wyoming Division	1° Curve	31 Rails
													3° 7' Curve	36 Rails
DRG & W	133 RE	High Silicon-CF & I	13138	0.72	0.93	0.021	0.030	0.65	-	-	May 1954	Kremmling, Colo.	4 - 12° Curves	123 Rails
AT & SF	132 RE	High Silicon-CF & I	6778	0.78	0.89	0.021	0.025	0.60	-	-	Oct. 1954	Raton Canyon	9° 52' Curve	1 Heat
												Colorado Division	10° 24' "	
													9° 0' "	
													10° 0' "	
N & W	132 RE	Heat Treated-Steelton	81033	0.77	0.85	0.01	0.03	0.17	-	-	Aug. 1954	Maher, W.Va.	6° 0' "	132 Rails
			87062	0.75	0.80	0.01	0.04	0.16	-	-		Looney's Curve, W.Va.	Compound	
			88059	0.75	0.85	0.01	0.03	0.16	-	-			4° - 7° -12°	109 Rails
AT & SF	1360	High-Silicon-Vanadium CF & I	7-037	0.77	0.89	0.029	0.018	0.60	-	0.12				1 Heat

The installation at Funston showed the effect of abrasion to a lesser degree, but here also no evidence of gage corner defects associated with shelling could be noted on the control-cooled or high-silicon rails. Curve oilers were not in operation on either curve.

Duluth, Missabe and Iron Range Railway Company Service Test of 115 RE Chrome–Vanadium Alloy Rail

This test was installed in March 1954 in curves at three different locations where the majority of the rail failures were caused by shelling under ore traffic. The location on Proctor Hill, near Duluth, Minn., had been in a test of water-quenched heat-treated rail reported in the AREA Proceedings, Vol. 53, 1952, page 899. The location consists of curve M. P. 3.93 and curve M. P. 3.58 of the Iron Range Division main line. Curve M. P. 3.93 has a 2-deg curvature and a descending grade of 2.00 percent. This installation consists of 52 C–V and 40 standard control-cooled rails, both on the high and low sides of the curves. The second curve on this location is at M. P. 3.58 and has a 4-deg curvature and a descending grade of 2.04 percent. It consists of 21 C–V and 20 standard control-cooled rails on both the high and low rails. The second location is curve M. P. 26.65 of the Iron Range Division main line. It has a curvature of 6 deg and a descending grade of 1 percent. It consists of 27 C–V and 17 standard control-cooled rails on both the high and low rails. The third location is the curve at M. P. 32.2 of the Iron Range Division main line. It has a curvature of 4 deg and a descending grade of 1.38 percent. The installation consists of 30 C–V and 30 standard control-cooled rails. The traffic over these curves is primarily iron ore carried in closely coupled, short (22 ft long), 50 and 70-ton ore cars on 33-in diameter wheels.

It is of interest that the 4-deg curve at M. P. 3.59 is of G.E.O. construction and the 4-deg curve at M. P. 32.2 consists of standard construction. The 6-deg curve at M. P. 26.65 is of interest in that a considerable abrasion as well as a shelling problem exists. Ore trains entering the dock area over this curve have their retainers set and use a great amount of sand.

Curves M. P. 3.93 and M. P. 3.58 had 40,000,000 gross tons of traffic over them at the date of the inspection. The standard control-cooled rail showed a considerable number of medium to heavy flakes and one rail on Curve M. P. 3.93 had two shelly spots. The C–V rail had no flaking, but showed head checks throughout.

The curves at M. P. 32.2 and M. P. 26.65 had carried 25,000,000 tons of ore traffic. On the curve at M. P. 32.2, one C–V rail showed some medium flaking and the balance had head checks. The standard control-cooled rail had light and medium flaking on the majority of the rails.

The curve at M. P. 26.65 showed a large amount of abrasion and medium and heavy flaking on the standard control-cooled rails, rather high up on the head. The C–V rail showed some curve wear, but not to the extent of the standard rail, and very little evidence of gage corner defects. Rail C–V 976186 D–25 is of interest in that it has outlasted two standard control-cooled rails. It is a rail leading into a switch. On this location two standard rails are used per season.

Curve oilers were in operation on curves 32.2 and 26.65.

Chesapeake and Ohio Railway Service Test of 132 RE Heat-Treated Rails

This test installation is near Martha, W. Va., on the Logan Subdivision of the Huntington Division, in a 3-deg 6-min curve on both the high and low sides. Twelve heat-treated and 12 standard control-cooled, mill-end-hardened rails were laid on May 2, 1949.

The 24 test rails consisted of 16 rails from 1 heat and 8 rails from another heat, with 8 rails and 4 rails from the 2 respective heats being heat treated and a like number being standard control-cooled and mill end hardened. The heat-treated rails were laid in the receiving end of the curve, followed by the standard control-cooled rails. Six of each type were laid on both the high and low sides of the curve.

At the time of the 1955 inspection, 192,200,000 gross tons of traffic had been over this track. Medium flaking and head checks were noted on all but one of the standard control-cooled rails. On two of these standard control-cooled rails shelling had developed and black spots had developed on three others.

Light flaking and head checks were noted on five of the heat-treated rails. Small black spots were also noted on all of these rails. The only other heat-treated rail was free of any gage corner defects.

The head flow of the heat-treated low rails was noted to be less than that of the standard control-cooled rails. At this particular installation it was of interest to note that gage corner defects appeared higher on the head of the rail than at other installations.

Norfolk and Western Railway Service Test of 132 RE Heat-Treated Rails

This test was installed in the main line, westbound track of M. P. NA 6, west of the station at Kermit, W. Va., in a 6-deg curve on both the high and the low sides. The 23 heat-treated and the 24 standard control-cooled, mill-end-hardened rails were laid on May 3, 1949.

The 47 test rails were from 2 heats; 15 heat-treated and 16 standard control-cooled rails were from 1 heat, and 8 of each type were from another heat. Standard control-cooled rails were laid through the tunnel, followed just west of the tunnel exit by 6 control-cooled end-hardened test rails on both the high and the low sides, followed by 12 and 11 heat-treated rails on the high and low sides, respectively. On the leaving end of the curve this was followed by standard control-cooled rails on both the high and low sides.

It was reported that at the time of the 1954 inspection all of the original standard test rails had been removed. One heat-treated rail had been removed on account of a severe engine burn.

At the time of the 1955 inspection, 263,000,000 gross tons of traffic had passed over this track. On the high side of the curve 2 of the remaining 11 heat-treated rails were free of gage corner defects. Black spots and head checks were noted in 3 other heat-treated rails and shelling of various degrees of severity had developed in the other 6 rails. The 10 heat-treated rails on the low side of the curve were in very good condition, with only a moderate amount of headflow.

It is interesting to note that since the installation of the test in 1949, the third set of standard control-cooled rails has been laid in the remainder of the curve adjacent to the test rails. Flaking and shelling have already developed to a greater extent in this third set of standard control-cooled rails than in the original heat-treated test rails.

Norfolk and Western Railway Service Test of 132 RE Heat-Treated Rails

This test was installed in a 6-deg curve near Maher, W. Va., at M. P. N 481 + 210, on August 2, 1954. Sixty-six heat-treated rails were installed on both the high and the low sides of this curve.

At the time of the 1955 inspection approximately 30,000,000 gross tons of traffic had passed over this installation. There was no evidence of a curve oiler functioning. Light

head checks were noted on practically every rail on this curve and 15 rails showed flaking to some degree.

This test was installed on the compounded 4-deg, 7-deg, 12-deg Looney's curve at M. P. N 445 + 582, W. Va., on August 9, 1954. Fifty-five heat-treated rails were laid on the high side of the curve and 54 on the low side.

At the time of the inspection insufficient tonnage had passed over this installation to have caused any gage corner development. The rails were well lubricated by a curve oiler. It was noted that 6 gage rods to the rail length were installed throughout the curve for the purpose of maintaining the gage on this curve, where 8 by 18-in tie plates with a 1 in 40 cant and 1¼-in eccentricity were used. This should be of interest in that it will have some bearing on the effect of gage on shelling. Heavy shelling was noted in the adjacent eastbound track which, for the most part, carried the empty coal car traffic. The service is comparatively light, but nevertheless shelling had developed.

Pennsylvania Railroad Service Test of 155 PS Heat-Treated Rails

The test was installed in the No. 1 eastbound track on curve No. 11 of the Middle Division near Forge, Pa. This is a 6-deg curve with a 0.5 percent descending grade, with the test rails on the high side only, consisting of 12 heat-treated and 12 standard control-cooled, end-hardened rails. This test was installed on January 19, 1949. The elevation of the high rail of this curve is 6 in and the authorized speed is 40 mph.

The 24 test rails consisted of 12 rails from each of 2 heats, of which 6 rails from each were heat treated and 6 were not heat treated. The rails were laid in the following sequence, beginning at the receiving end of the curve: 2 standard control-cooled end-hardened rails, 2 heat-treated rails, 2 standard control-cooled end-hardened rails, etc.

The original test rails were all in service at the time of the 1955 inspection and had carried 320,000,000 gross tons of traffic. Only 1 of the heat-treated rails was free of gage corner defects. Light flaking was noted on the remaining 11 heat-treated rails. Black spots were noted on 6 of these rails and shelling on 3 of them.

Medium to heavy flaking was common to all of the standard control-cooled rails. A considerable number of black spots were found on each of the 7 rails and shelling on 11 rails. The shelled areas were relatively small with the exception of 2 rails on the receiving end of the curve. Considerable curve wear was common to all rails and accounts for a better condition of the gage corner defects as compared to the last inspection. The standard control-cooled rail showed more curve wear than the heat-treated rail. Figs. 1 and 2 illustrate in general the condition of this test. The photographs were obtained through the courtesy of C. J. Code, assistant chief engineer—Tests, Pennsylvania Railroad.

Pennsylvania Railroad Service Test of 155 PS High-Silicon Rails East of Lewistown, Pa.

This test was installed on October 1953, from a heat of steel with a high silicon analysi s on a curve on No. 1 eastbound passenger track near Lewistown, Pa. The high-silicon rails were laid in groups of five alternately with groups of five standard control-cooled rails on both high and low sides of the curves.

This test is on a 2-deg 37-min curve, which is considered as an intermediate curvature. Shelling on this type of curve develops slowly and only a moderate amount of shelling had been observed on this particular curve on previous standard control-cooled rail.

Fig. 1—Heat-treated rail, curve 11, track No. 1, Pennsylvania Railroad, Middle Division, 320,000,000 gross tons of traffic.

Fig. 2—Standard CC rail, curve 11, track No. 1, Pennsylvania Railroad, Middle Division, 320,000,000 gross tons of traffic.

At the time of the inspection approximately 45,000,000 gross tons has passed over the curve. Even at this early stage a marked difference was noted in the development of gage corner defects between the two types of rails. Only one high-silicon rail had a 6-in area of flaking. Light head checks were noted on other rails of this type. Heavier head checks and light flaking were noted on most of the standard control-cooled rail.

PROGRESS REPORT ON SERVICE TEST OF 115 RE HEAT-TREATED RAIL ON THE GREAT NORTHERN RAILWAY

This test was installed to investigate the resistance to shelling of heat-treated rail under ore traffic. This installation is located on the Mesabi Division of the Great Northern Railway. It consists of two 4-deg curves, located 3–5 miles west from the Carlton Tower, which is 25 miles from Superior, Wis. The service life of standard control-cooled rail on these curves has been 5–7 years. The removal of this rail has been necessary due to excessive shelling. These two curves were laid on February 15, 1951, with 115 RE heat-treated rail on curve 20 and 115 RE standard control-cooled rail on curve 22, both high and low sides. The first standard control-cooled rail had to be removed from service on account of shelling at 130,000,000 tons of traffic. On August 1, 1955, at 193,000,000 tons of traffic, the high side on this entire curve had to be relaid. The heat-treated rail at this phase of the investigation has practically no indication of serious shelling.

The following detailed information on these two curves will be of interest. The average traffic over curves 20 and 22 has been 40,000,000 tons per season, mostly ore. The maximum authorized speed for ore and freight trains over this territory is 40 mph, and the maximum authorized speed for passenger trains is 50 mph. Both curves are on a 0.4 percent descending grade. Curve lubricators are used to protect the high rails. These curve lubricators have been observed to be functioning during the major part of the test.

Curve 20, which has the heat-treated rail on both the high and low sides, is a left hand curve 1121 ft long, with an elevation of 3 in. The 85 rails of the 115 RE section were produced at the Steelton Plant of Bethlehem Steel Company. The analysis was 0.76 C, 0.85 Mn, 0.014 P, 0.037 S, and 0.19 Si. A King Brinell Hardness Tester was used in obtaining hardness readings of 321–375 after this rail was in track 3 months.

Curve 22, which has the standard control-cooled rail on both the high and low sides, is a comopund of 4 deg and 4 deg 39 min. It is a right-hand curve 875 ft and 462 ft long, respectively. It has an elevation of 3 in. This rail was made at Gary Steel Works of the USS Corporation. The majority of this rail was taken from heat No. 973934, with analysis of 0.76 C, 0.84 Mn, 0.016 P, 0.032 S, and 0.16 Si. A range of Brinell hardness readings of 269–286 was obtained with a King Hardness Tester after this rail was in track 3 months.

Test rails from both curves were submitted for rolling-load tests at the University of Illinois. Professor R. E. Cramer reported the following results in the AREA Proceedings, Vol. 53, 1952, page 903:

Size and Kind of Rail	*Avg. BHN*	*Cycle to Failure 50,000-Lb Wheel Load*
Gary 115-lb, as rolled	271	1,565,000
Bethlehem 115-lb, Heat-Treated	379	9,625,000

This installation was closely checked at least once a year in conjunction with the railroad and steel producer's personnel. The development of the shelling in the earlier

stages followed the pattern observed on other installations. At first head checks were observed, then light flaking, which worked into heavy flaking and finally black spots. This occurred fairly rapidly in the standard control-cooled rail, until in 1954 one rail had to be removed as indicated by the detector car for shelling. This rail is shown on Fig. 1 after removal from track. Fig. 3 and Fig. 4 illustrate the general condition of the standard control-cooled rail at 130,000,000 tons of traffic. Figs. 2, 5 and 6 illustrate, in general, the condition of the heat-treated rail on curve 20 at 130,000,000 tons of traffic. Due to the presence of a considerable number of detected detail fractures from shells, curve 22, consisting of standard rail, was relaid on the high side on August 1, 1955, at 193,000,000 tons of traffic. Fig. 7 shows the general condition of the rails. Figs. 8, 9, 10 and 11 illustrate the general condition of flaking and shelling. It was observed that some of the shelling occurred over the joint bar area. The heat-treated rail, in general, appeared to be in excellent condition, as shown in Figs. 12 to 15. The rail on Fig. 15 showed the most severe case of flaking or possible shelling observed on curve 20, consisting of heat-treated rail. It must be noted that the condition of the rail at 193,000,000 tons of traffic appears to be better from the standpoint of severity and number of defects than it was at 130,000,000 tons of traffic. This can be attributed to the fact that the curve oiler had not functioned for several weeks and some of the defects had been abraded. On curve 20 it was observed that the major part and the more severe indications of flaking occurred on the leaving end of the curve.

The observations on the installation show a very definite advantage of the heat-treated rail over the standard control-cooled rail. A full evaluation of the advantage will be arrived at in the future, when the heat-treated rail will have been removed. A question has arisen as to whether this is a true value. For test purposes, neither type of rail was transposed, which explains the short 4-year life of the standard rail on the curve, which had a previous 5 to 7-year life with transposing. If both types of rail in the course of the test could be transposed as in standard practice, a much greater life could be obtained.

A question has been raised by the observers in the case of depressed areas at several of the ends of the heat-treated rails in regard to cause. It is believed that these could be caused by weeping cracks or another phenomenon of shelling over the rail ends.

During the investigation it was noted that during periods when the curve oiler was not operating, the severity and number of gage corner defects, especially in the earlier stages, decreased due to abrasion. In view of this fact, it will be of interest to note the effect of curve wear at various tonnages, as shown on the attached drawings. The accompanying drawings represent the average contours taken on every other rail on curves 20 and 22 at the gross tonnages shown. The contours of the high and the low rails of standard control-cooled rail showed a maximum wear of 7.2 percent of the high rail and 3.8 percent of the low rail. The heat-treated rail did not show measurable wear until the standard rail was taken out of service. The wear of the heat-treated rail at this point was 2.8 percent for the high rail and 2.6 percent for the low rail.

It must be noted that no head flow occurred on the low rails of curves 20 and 22.

(The figures and drawings referred to above are presented on the following pages).

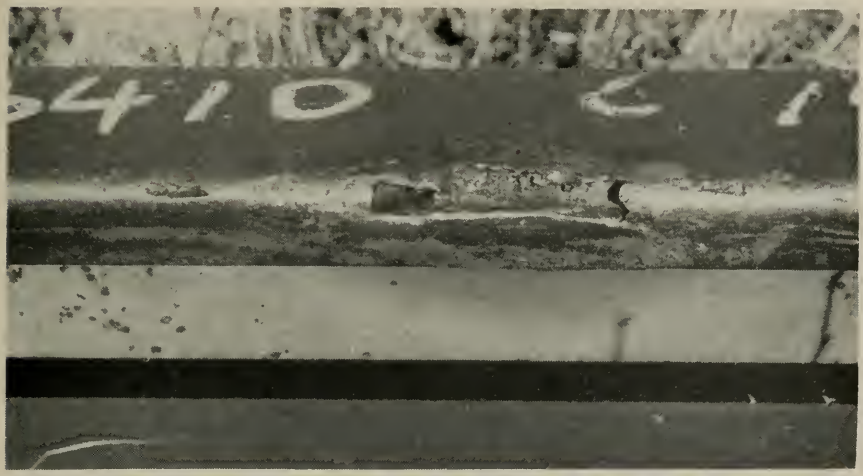


Fig. 1—Control-cooled rail removed from service because of shelling at 130,000,000 tons of traffic.

Fig. 2—Heat-treated rail showing head checks at 161,000,000 tons of traffic.

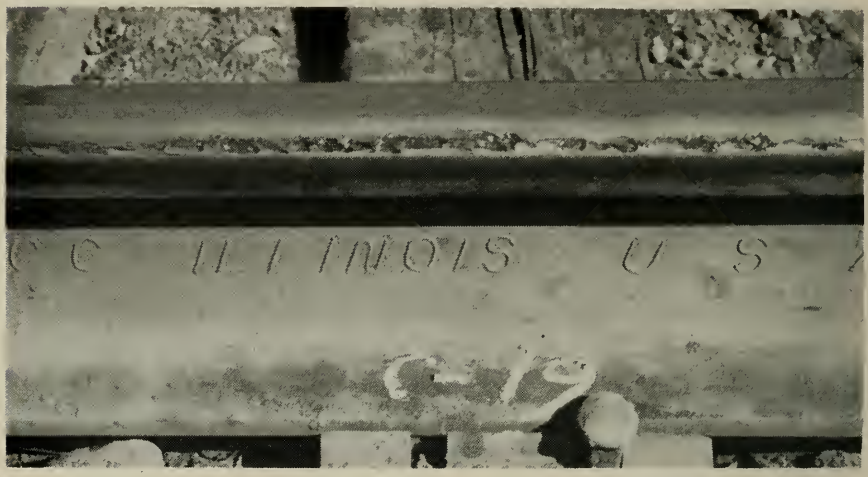


Fig. 3—Control-cooled rail showing heavy flaking at 130,000,000 tons of traffic.

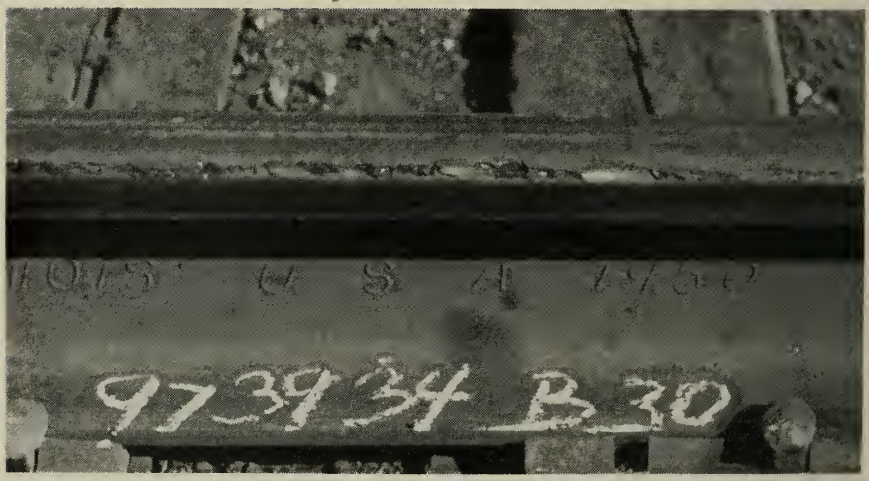


Fig. 4—Control-cooled rail showing heavy flaking at 130,000,000 ton of traffic.

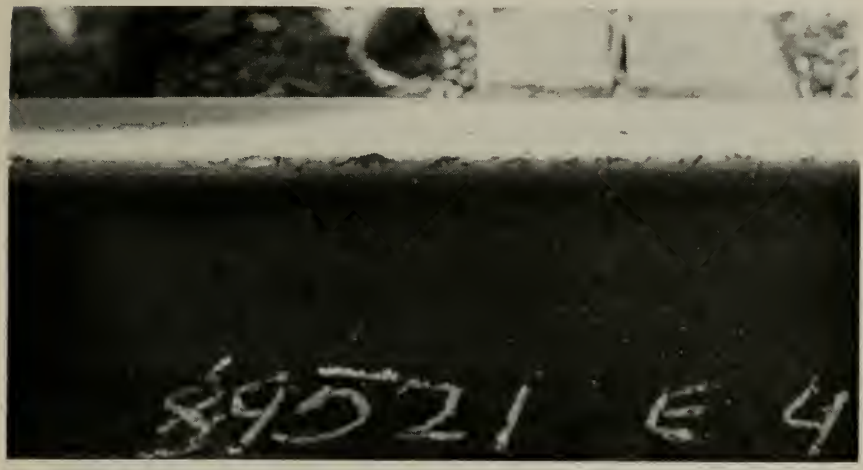


Fig. 5—Heat-treated rail showing medium flaking at 130,000,000 tons of traffic.

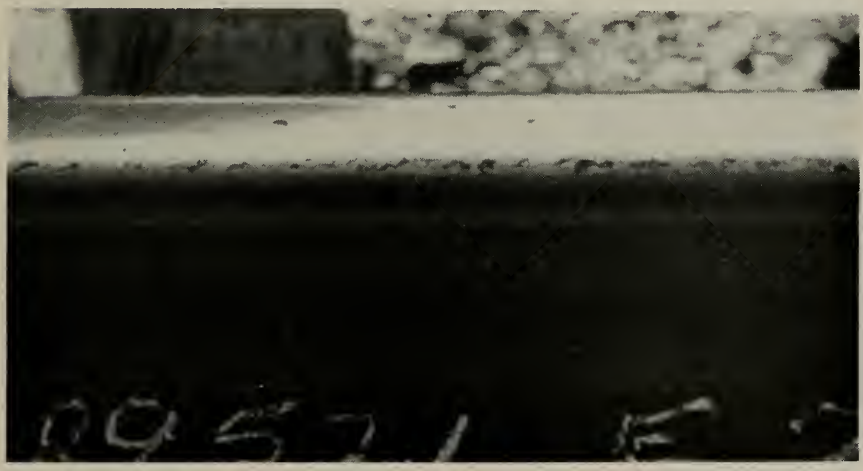


Fig. 6—Heat-treated rail showing medium flaking at 130,000,000 tons of traffic.

Fig. 7—Control-cooled rails removed from service at 193,000,000 tons of traffic.

Fig. 8—Control-cooled rail showing shelling at end removed from service at 193,000,000 tons of traffic.

Fig. 9—Control-cooled rail showing detail fracture from shelling removed from service at 193,000,000 tons of traffic.

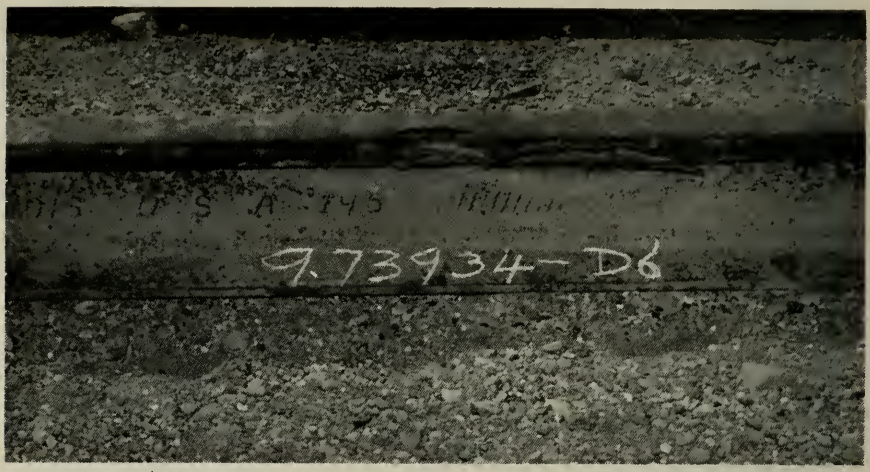


Fig. 10—Control-cooled rail showing shelling removed from service at 193,000,000 tons of traffic.

Fig. 11—Control-cooled rail showing heavy flaking removed from srevice at 193,000,000 tons of traffic.

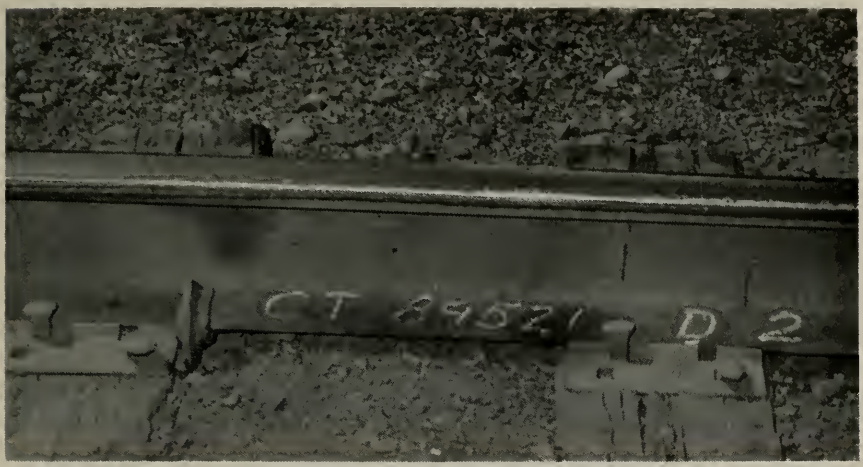


Fig. 12—Heat-treated rail showing light flaking at 193,000,000 tons of traffic.

Fig. 13—Heat-treated rail showing medium flaking at 193,000,000 tons of traffic.

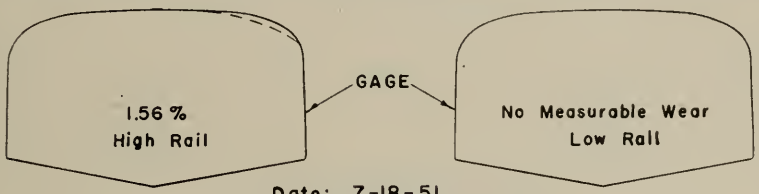
Fig. 14—Heat-treated rail showing light flaking at 193,000,000 tons of traffic.

Fig. 15—Heat-treated rail showing heavy flaking at 193,000,000 tons of traffic.

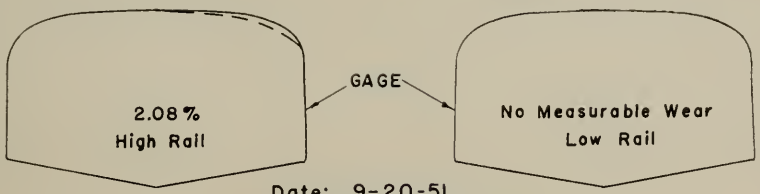
1

CURVE WEAR ON THE GREAT NORTHERN RY.
115 LB. R.E. CONTROL COOLED RAIL

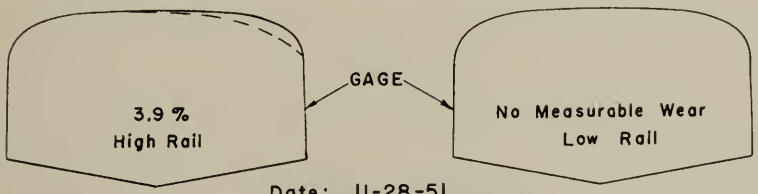
Mesabi Division, Lake District, Between Boylston and Brookston
M.P. 33+8, Curve No. 22, Degree 4°, Mill Illinois, Kind 115#, Rolled 10-50,
Laid 2-7-51.



Date: 7-18-51
21,300,155 GROSS TONS



Date: 9-20-51
35,103,892 GROSS TONS



Date: 11-28-51
44,500,178 GROSS TONS

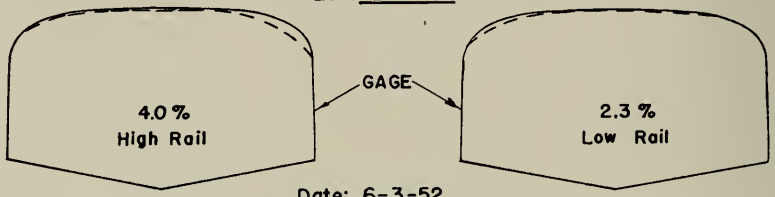
S

2

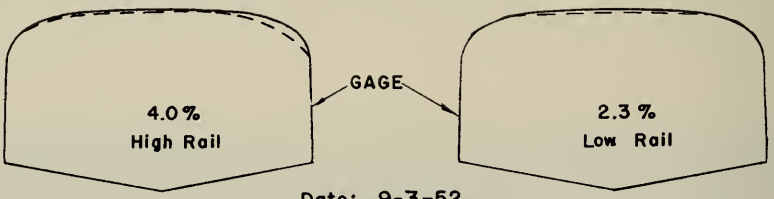
CURVE WEAR ON THE GREAT NORTHERN RY.

115 LB. R.E. CONTROL COOLED RAIL

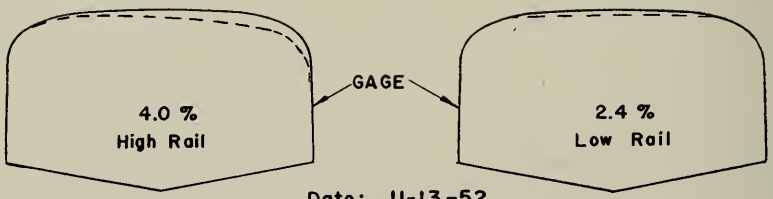
Mesabi Division, Lake District, Between Boylston and Brookston
M.P. 33+,8, Curve No.22, Degree 4°, Mill Illinois, Kind 115#, Rolled 10-50,
Laid 2-7-51.



Date: 6-3-52
56,082,051 GROSS TONS



Date: 9-3-52
65,854,870 GROSS TONS

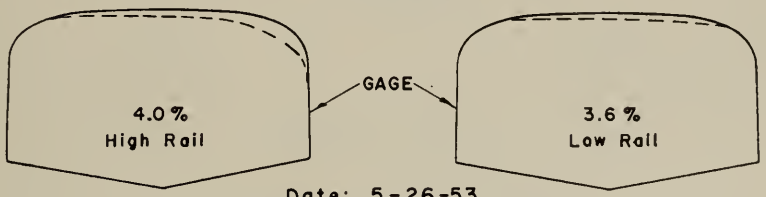


Date: 11-13-52
82,786,291 GROSS TONS

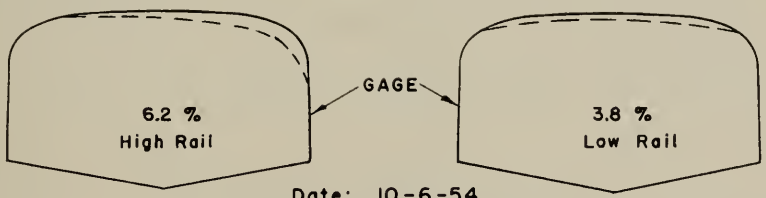
3

CURVE WEAR ON THE GREAT NORTHERN RY.
115 LB. R.E. CONTROL COOLED RAIL

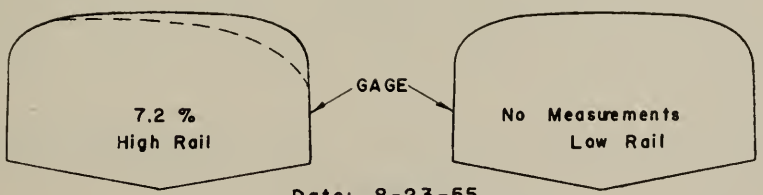
Mesabi Division, Lake District, Between Boylston and Brookston
M.P. 33+.8, Curve No. 22, Degree 4°, Mill Illinois, Kind 115#, Rolled 10-50,
Laid 2-7-51.



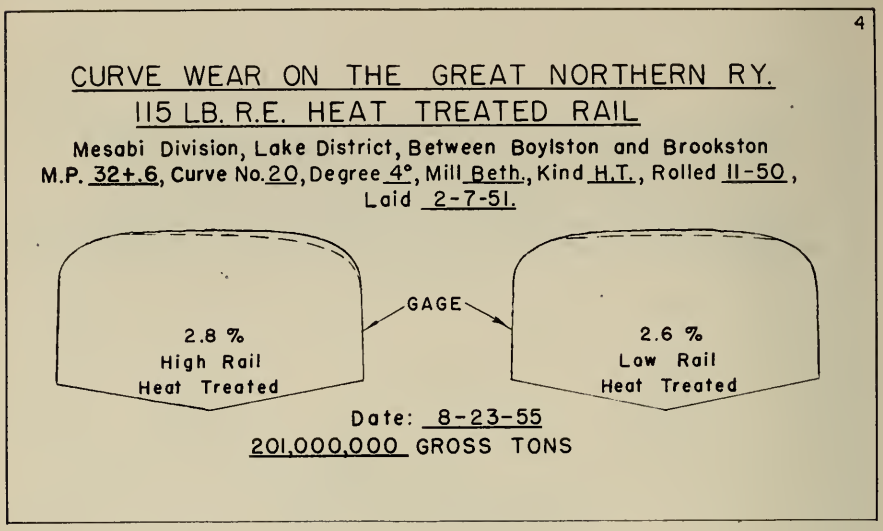
Date: 5-26-53
96,730,076 GROSS TONS



Date: 10-6-54
151,000,000 GROSS TONS



Date: 8-23-55
201,000,000 GROSS TONS



Appendix 8–a

Fourteenth Progress Report on Shelly Rail Studies at the University of Illinois

By R. E. Cramer
Research Associate Professor, University of Illinois

Organization and Acknowledgment

The shelly rail studies at this laboratory are financed equally by the Association of American Railroads and the American Iron and Steel Institute. Thirteen previous reports have been published annually in the Proceedings of the American Railway Engineering Association. The research program is supervised by a committee composed of engineers from both the AREA Rail committee and the AISI Technical Committee on Rails and Joint Bars.

R. T. Murphy, a student test assistant, has worked on this investigation on a part-time basis during the past year. Marion Moore, mechanic, has operated the rolling-load machines.

Rolling-Load Tests of High-Silicon Rails

Nine high-silicon rails were supplied the investigation by the Colorado Fuel & Iron Corporation for rolling-load tests. Two rolling-load tests are reported in Table 1 on each rail, together with chemical analysis, Brinell hardness and mechanical tests of the steel. Fig. 1 shows the shelling cracks produced in most of these rails. Figs. 2 and 3 show photographs of 10 of these high-silicon rails. The number of cycles for failure of the 18 tests range from 970,700 to 2,243,000, with an average of 1,422,400. This is lower than the average of 2,307,200 for 10 tests reported in the Thirteenth Report printed on

TABLE 1—PHYSICAL TESTS AND ROLLING-LOAD TESTS, OCTOBER 1, 1954, TO OCTOBER 1, 1955

Specimen No.	Chemical Analysis					Size and Kind of Rail	Avg. Brin. Hard.	Yield Str. 0.2% Psi	Tensile Str. Psi	Elong. in 2 in %	Red. Area %	Charpy Value		Endurance Limit Psi	Cycles for Failure 50,000-lb Wheel Load
	C	Mn	Si	Alloys								No Notch	Key Hole		
				Cr	Va										
1149'A	0.72	0.93	0.65	------	------	115-lb high-silicon	288	78,500	140,900	11.2	18.5	144	4.8	63,000	1,630,000
1149 B	0.72	0.93	0.65	------	------	Colorado for D&RGW	------	------	------	------	------	------	------	------	1,588,700
1150 A	0.72	0.93	0.65	------	------	115-lb high-silicon	285	76,600	142,700	11.7	20.2	154	4.6	65,000	2,243,000
1150 B	0.72	0.93	0.65	------	------	Colorado for D&RGW	------	------	------	------	------	------	------	------	1,905,000
1151 A*	0.641	0.51	0.41	1.11	0.16	Used 115-lb C-V*	363	117,000	117,000	10.	22.2	235	2.5	85,000	5,444,000
1151 B	0.641	0.51	0.41	1.11	0.16	Gary for DM&IR	------	------	------	------	------	------	------	------	1,846,000
1151 C	0.641	0.51	0.41	1.11	0.16		------	------	------	------	------	------	------	------	7,642,000
1151 A	0.79	0.82	0.74	------	------	133-lb high-silicon	297	78,800	147,000	9.8	14.4	110	4.5	66,000	2,075,000
1152 B	0.79	0.82	0.74	------	------	Colorado for UP	------	------	------	------	------	------	------	------	1,093,000
1153 A	0.75	0.89	0.60	------	------	133-lb high-silicon	296	75,200	141,500	10.6	17.0	127	5.5	63,000	1,472,000
1153 B	0.75	0.89	0.60	------	------	Colorado for UP	------	------	------	------	------	------	------	------	1,225,000
1154 A	0.75	0.89	0.60	------	------	133-lb high-silicon	283	78,700	143,300	10.7	17.7	92	3.4	64,000	1,078,200
1154 B	0.75	0.89	0.60	------	------	Colorado for UP	------	------	------	------	------	------	------	------	1,017,000
1155 A	0.79	0.82	0.74	------	------	133-lb high-silicon	294	77,900	144,700	10.3	14.1	115	7.0	64,250	907,600
1155 B	0.79	0.82	0.74	------	------	Colorado for UP	------	------	------	------	------	------	------	------	2,134,000
1157 A	0.75	0.79	0.62	------	------	133-lb high-silicon	293	77,900	144,500	9.5	15.0	117	2.8	60,500	2,017,000
1157 B	0.75	0.79	0.62	------	------	Colorado for UP	------	------	------	------	------	------	------	------	1,545,000
1158 A	0.75	0.88	0.55	------	------	133-lb high-silicon	288	74,400	142,000	10.0	14.9	108	4.3	62,500	1,200,000
1158 B	0.75	0.88	0.55	------	------	Colorado for UP	------	------	------	------	------	------	------	------	1,157,000
1160 A	0.75	0.88	0.55	------	------	133-lb high-silicon	283	75,200	142,000	10.2	14.0	105	7.1	61,500	1,344,000
1160 B	0.75	0.88	0.55	------	------	Colorado for UP	------	------	------	------	------	------	------	------	970,700
1163 A	0.80	0.86	0.16	------	------	136-lb standard rail	274	70,800	135,000	9.7	13.4	94	4.6	59,500	912,000
1163 B	0.80	0.86	0.16	------	------	Colorado Mill	------	------	------	------	------	------	------	------	1,143,300
1166 A	0.78	0.85	0.16	------	------	119-lb standard rail	258	71,400	128,700	12.2	20.0	112	5.8	58,250	860,000
1166 B	0.78	0.85	0.16	------	------	Colorado Mill	------	------	------	------	------	------	------	------	1,009,000

*This rail had 6 million tons of ore traffic before test.

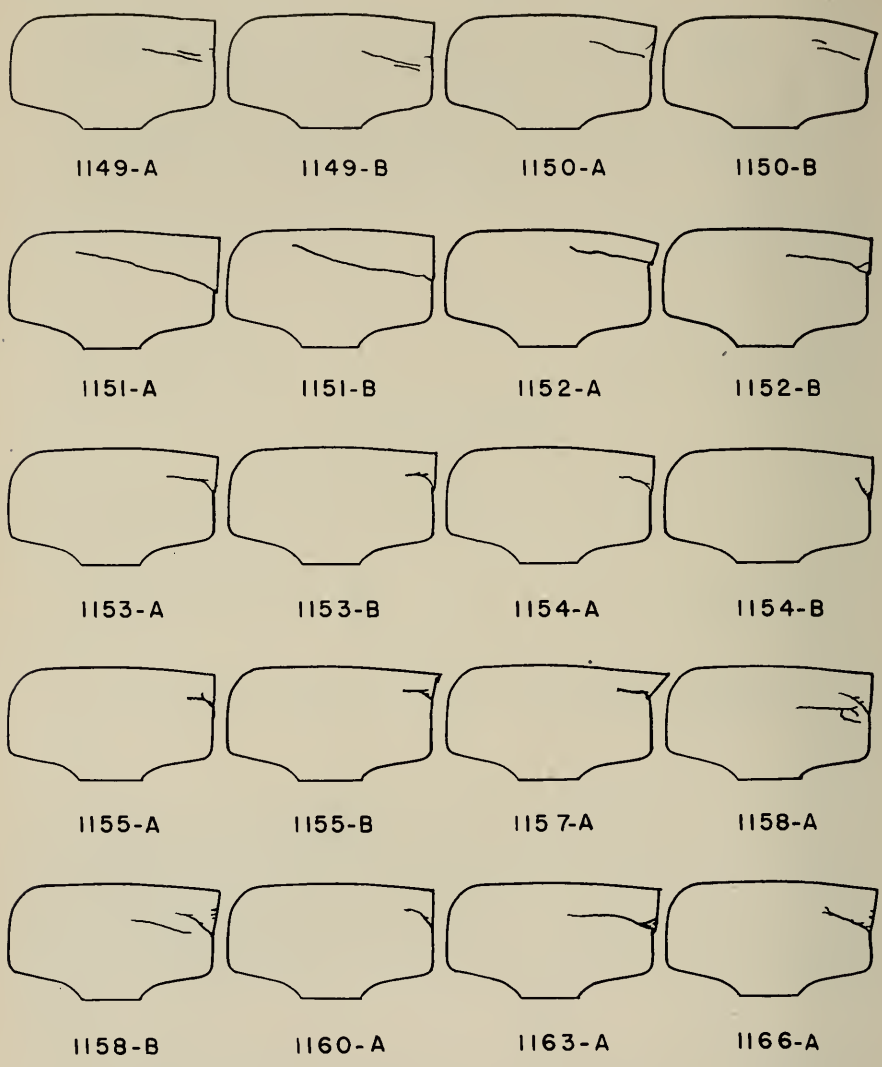


FIG. 1—LOCATION OF SHELLING CRACKS DEVELOPED IN ROLLING-LOAD MACHINE.

page 954 of the AREA Proceedings, Vol. 56, 1955. This difference is due to exceptionally high tests on 2 rails, Nos. 1147 and 1148, which averaged 2,298,000, and one freak test of 3,972,000 reported last year. It now seems that an average of around 1,500,000 to 2,000,000 cycles may be established as the expected life in the laboratory rolling-load tests for high-silicon steel rails. It was thought desirable to retest a few standard carbon-steel rails as reported in Table 1 on rails numbered 1163 and 1166. They gave rolling-

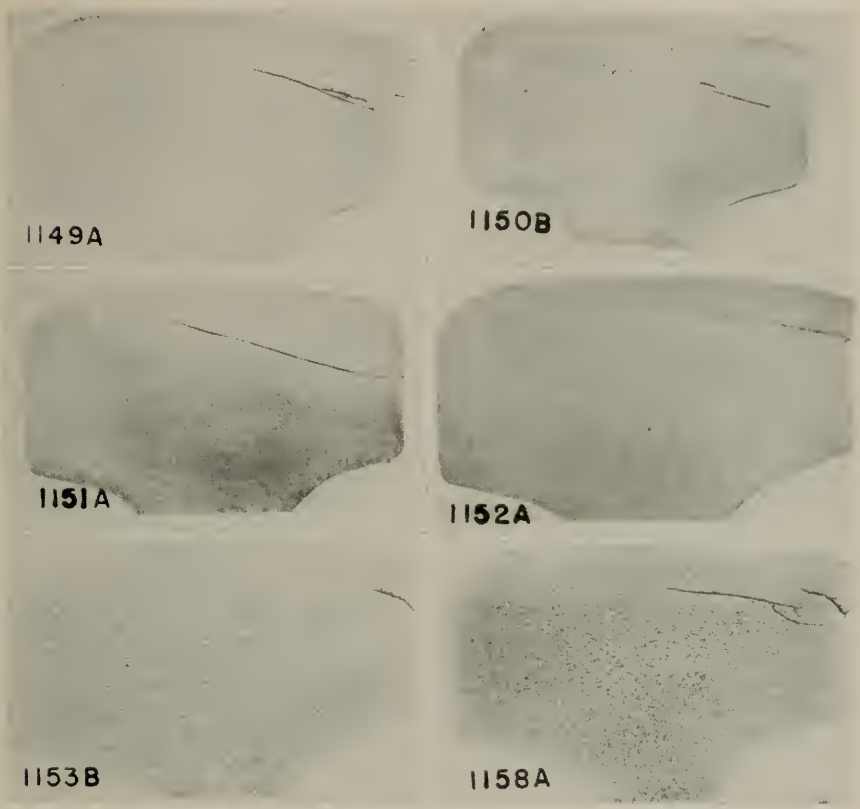


Fig. 2—Shelly failures produced in rolling-load tests.

Specimen Number	*Kind of Specimen*	*Average Brinell Hardness*	*Cycles of 50,000 Lb Wheel Load*
1149A	115-lb high-silicon rail	288	1,630,000
1150B	115-lb high-silicon rail	285	2,243,000
1151A	Used 115-lb chrom.-va. rail	363	5,444,000
1152A	133-lb high-silicon rail	297	2,075,000
1153B	133-lb high-silicon rail	296	1,225,000
1158A	133-lb high-silicon rail	288	1,200,000

load tests which average 967,000 cycles, which is in agreement with the 1,000,000 cycles considered the average of all standard carbon-steel rails previously reported.

Based on laboratory tests of 2 or 3 specimens, each from 16 high-silicon rails over the past 3 years, it now seems well established that high-silicon steel rails do last 50 to 100 percent longer than standard carbon-steel rails in laboratory tests. It is the writer's opinion that in track under lighter average wheel loads than used for laboratory tests,

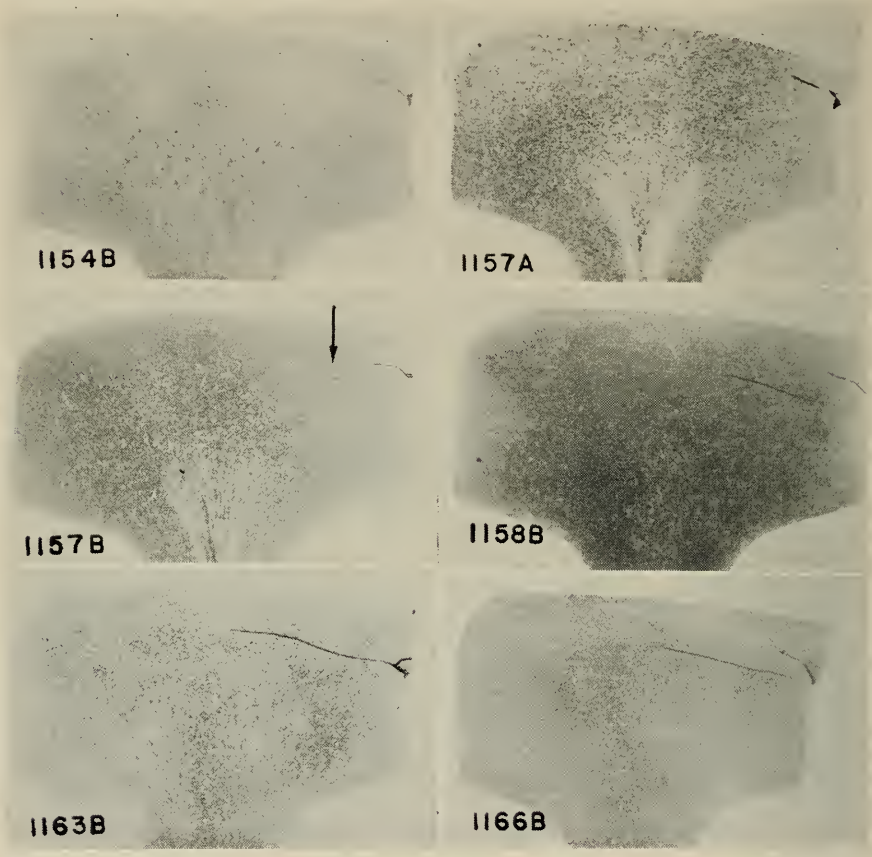


Fig. 3—Shelly failures produced in rolling-load tests.

Specimen Number	*Kind of Specimen*	*Average Brinell Hardness*	*Cycles of 50,000-Lb Wheel Load*
1154B	133-lb high silicon rail	283	1,017,000
1157A	133-lb high-silicon rail	293	2,017,000
1157B	133-lb high-silicon rail	293	1,545,000 *
1158B	133-lb high-silicon rail	288	1,157,000
1163B	136-lb standard carbon rail	274	1,143,000
1166B	119-lb standard carbon rail	258	1,009,000

the high-silicon rails may show even greater resistance to shelling and also considerably more resistance to curve wear than standard carbon-steel rails. It has been observed in laboratory tests that the rail heads of silicon-steel rails do not bulge or flow as fast under the heavy wheel loads as standard carbon-steel rails. Also, the shelling cracks do not seem to grow quite as fast in the high-silicon rails as in standard carbon-steel rails.

Rolling-Load Tests of One Chrome–Vanadium Rail

A specimen of 115-lb chrome–vanadium rail was supplied for rolling-load tests by H. A. Smith, chief engineer of the Duluth, Missabi & Iron Range Railroad. This specimen had been in track a few months and had been subjected to about 6 million tons of ore traffic before it was removed for the rolling-load tests. It is specimen No. 1151 in Table 1, with an average Brinell hardness of 363 over a cross section of the rail head. The first specimen from this rail developed a shelling crack at 5,494,000 cycles, but the second specimen failed at 1,846,000 cycles, which is our lowest test on a chrome-vanadium alloy rail. The average for 9 previous tests of chrome–vanadium rails was over 5,000,000 cycles. A third specimen from rail 1151 was then tested, which ran 7,642,000 cycles before failure. It appears that the second specimen, 1151B, was a freak test with exceptionally low cycles for failure. There was a very prominent segregation streak along the center line of the shelling crack.

Shelly Rail Failures from Service

Twenty-four detail fractures from shelling were sent to this laboratory for examination in the past year. A few of these had been improperly classified as transverse fissures, but more were in rails which had broken off the detector car mark and could not be classified except by laboratory examination. One group of six is all from the same heat of steel and was sent in for special examination. Laboratory tests on these six rails are not completed, but it has been found that some of them have more than normal segregation streaks.

Rolling-Load Tests to Produce Detail Fractures in the Laboratory

Eight rolling-load tests have been made since October 1, 1954, on high-silicon rails to produce detail fractures from shelling. These tests are listed in Table 2.

Table 2—Rolling-Load Tests to Produce Detail Fractures

(All tests used 50,000-lb wheel loads with slots 6 in long and 5 in below the rail tread)

Specimen Number	*Size and Kind of Rail*	*Average Brinell Hardness*	*Cycles in Rolling Machine*	*Remarks on Failure*
1144	133-lb high-silicon Colorado for UP	270	3,182,000	15% DF from Shelling
1148	132-lb high-silicon Colorado for AT&SF	300	5,917,000	Web Failure—No Shelling Crack
1141	133-lb high-silicon Colorado for D&RGW	295	1,238,000	10% DF from Shelling
1152	133-lb high-silicon Colorado for UP	297	887,800	40% DF from Shelling
1153	133-lb high-silicon Colorado for UP	296	972,000	25% DF from Shelling
1158	133-lb high-silicon Colorado for UP	288	2,011,500	25% DF from Shelling
1154	133-lb high-silicon Colorado for UP	283	3,222,000	20% DF from Shelling
1160	133-lb high-silicon Colorado for UP	283	1,640,000	25% DF from Shelling

As has always been the case with rolling-load tests made to produce detail fractures from shelling, a considerable variation in results is found in the cycles for failure. Fig. 4 shows six of the fractures produced. Five of these fractures show clearly that they developed from a shelling crack. The sixth, rail 1144, does not show the shelling crack, but by examining the specimen under magnification, a small shelling crack was found, and it is evident that the transverse fatigue area started inside the rail head and had not reached the surface when the final fracture occurred. No conclusions can be drawn from these

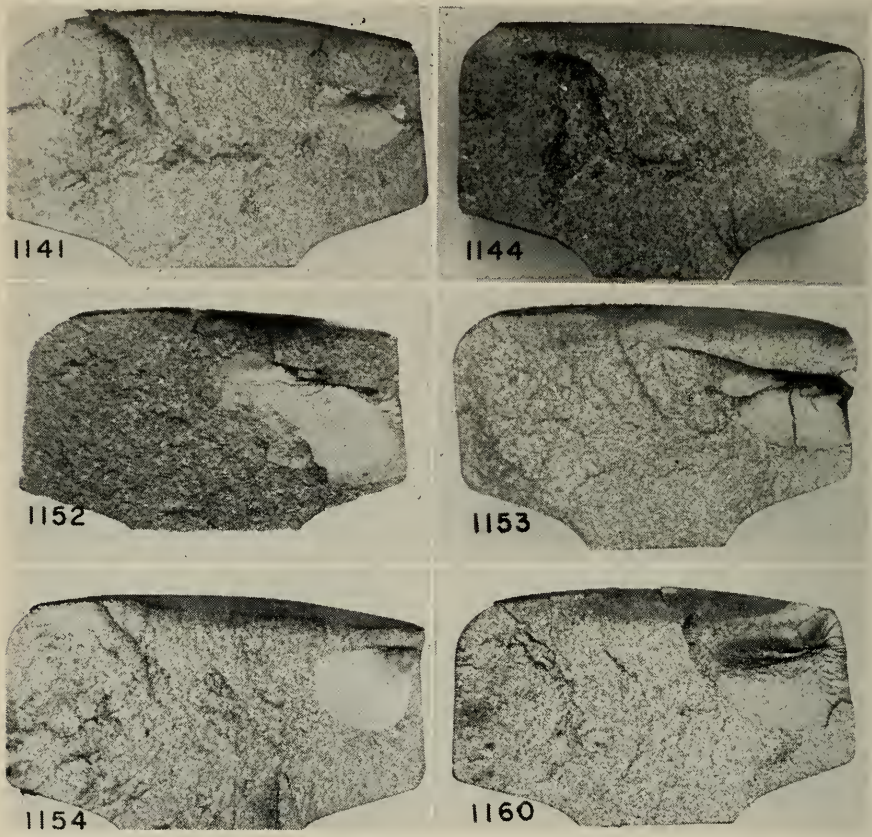


Fig. 4—Specimens tested to produce detail fractures.

Specimen Number	*Kind of Rail*	*Type of Fracture*	*Cycles of 50,000 Lb Wheel Load*
1141	133-lb. high-silicon	10% D. F. from shelling	1,238,000
1144	133-lb high-silicon	15% D. F. from shelling	3,182,000
1152	133-lb high-silicon	40% D. F. from shelling	887,800
1153	133-lb high-silicon	25% D. F. from shelling	972,000
1154	133-lb high-silicon	20% D. F. from shelling	3,222,000
1160	133-lb high-silicon	25% D. F. from shelling	1,640,000

few tests as to the resistance of high-silicon rails to the development of detail fractures from shelling, but it is interesting to be able to produce such failures in a few weeks in the laboratory which closely resemble those that develop in track. Further tests to produce detail fractures in laboratory tests will be continued.

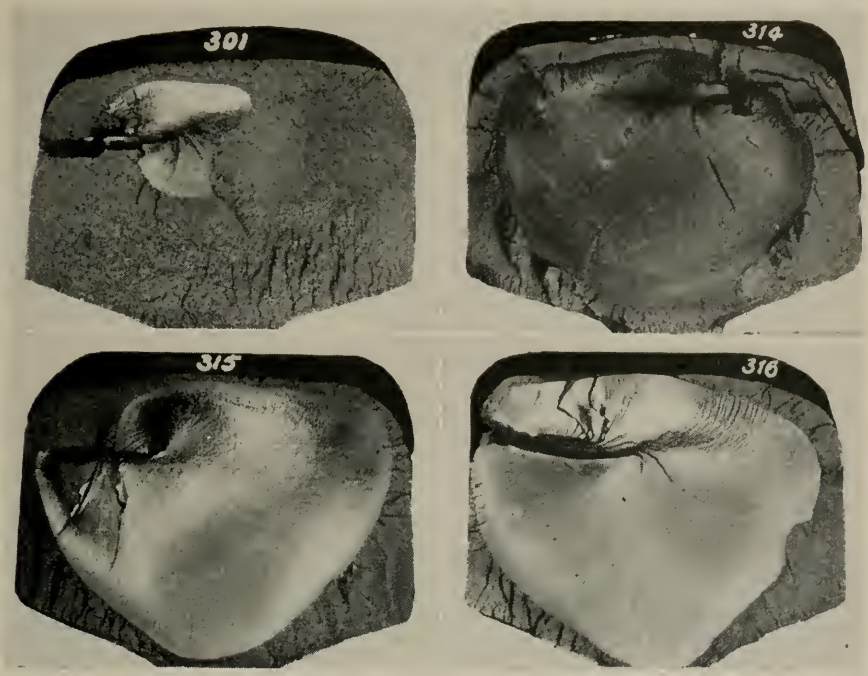


Fig. 5—Four failures in French railroad rails which resemble detail fractures from shelling.

Detail Fractures from Shelling in European Rails

The writer saw a number of pictures of rail failures in Europe which would be classified as detail fractures from shelling in the United States. This term is not used in Europe. J. Palme of Paris, France, in charge of the Subdivision of Rails of the French National Railroads, gave the writer several pictures of failed rails. The ones which most resemble detail fractures are specimens which were rusted or the pictures are small and not suitable for reproduction. However, four excellent pictures are shown in Fig. 5. These failures resemble detail fractures from shelling, except that the longitudinal shelling cracks are deeper than in most American rails, except No. 314. The failure in this specimen is very similar to some American detail fractures.

Summary

1. High-silicon rails give laboratory rolling-load tests 50 to 100 percent better than standard carbon-steel rails before developing shelling failures.

2. Three tests of a 115-lb chrome–vanadium alloy rail gave 2 tests over 5,000,000 cycles and 1 test of 1,846,000 cycles.

3. Rolling-load tests of high-silicon rails to develop detail fractures from shelling produce failures similar to those produced in track.

4. Detail fractures from shelling develop in European Rails (see Fig. 5), but this classification of failure is not used in Europe.

Report on Assignment 9

Recent Developments Affecting Rail Sections

W. J. Cruse (chairman, subcommittee), W. D. Almy, E. L. Anderson, F. W. Biltz, T. A. Blair, C. B. Bronson, C. J. Code, L. S. Crane, P. O. Ferris, S. R. Hursh, K. K. Kessler, L. R. Lamport, C. C. Lathey, Ray McBrian, B. R. Meyers, W. G. Powrie, R. B. Rhode, G. L. Smith, H. F. Whitmore, R. P. Winton, Edward Wise, Jr.

This is a progress report, presented as information.

The topics being pursued under this assignment are:

(a) Redesign of 100 RE rail and joint bars.

(b) Study of the proposal for the adoption as an AREA standard of a headfree joint bar for the 140 RE rail section.

(c) Investigation of a velocity power punch for punching holes in rail.

The study of the redesign of 100 RE rail and joint bars was discontinued following a canvas of chief engineers of member roads which disclosed that less than two percent would use this rail if available.

A survey of the proposal for the adoption as an AREA standard of a headfree joint bar for the 140 RE rail section has been completed. This headfree bar is for use as an alternate for railroads desiring a headfree bar in preference to the head-contact bar.

With reference to the velocity power punch, tests made at the AAR Research Center with the Sonntag fatigue testing machine of a piece of 115-lb rail in which holes had been punched by the TP & W forces at low temperature showed excellent results. The fatigue strength of the specimen so punched was higher than that of a similar specimen in which the holes had been drilled.

Earlier investigation at the Pennsylvania Railroad laboratory at Altoona had shown cracks in the rail web of 100-lb and 112-lb rails punched at low temperature. No fatigue tests were included.

In view of these conflicting results, additional rails were punched in September 1955. These tests were conducted by the laboratory personnel under Mr. Code's supervision and were witnessed by G. M. Magee, director of engineering research, AAR, and Mr. Bolda of the Southern Railway. The velocity power punch was operated by representatives of the manufacturer. All rails were of 100-lb PS section, 6 ft long. Three holes were punched in each end of each piece. There were two new open-hearth rails with sawed ends, two new open-hearth rails with torch cut ends, and one piece of slightly worn Bessemer rail. The open-hearth rails were of two different heats.

Cracks were developed in the rail webs of three of the four open-hearth rail ends which had been torch cut—which were punched at temperatures of 0 to 64 deg. One rail end punched at 15 to 19 deg developed no cracks.

Cracks were developed in the pieces of open-hearth rail with sawed ends punched at –12 to 0 deg, and in one end at 16 to 29 deg. No cracks were developed in another end at 25 to 29 deg, or in another at 61 to 62 deg.

Cracks were developed in both ends of the Bessemer rail which had torch cut ends, one of which was punched at 15 to 22 deg and one at 63 to 64 deg. All temperatures reported are Fahrenheit.

The Southern Railway had also found cracks in some rail ends punched with this tool.

In view of these results, representatives of the manufacturer are working on improvements in this tool which will better support the rail web on the side opposite the punch, and it is hoped that these will eliminate the cracks. When the improved velocity power punch is ready, tests will again be made at the Pennsylvania's laboratory at Altoona.

Report on Assignment 10

Service Performance and Economics of 78-Ft Rail Specifications for 78-Ft Rail

Collaborating with Committee 5

L. R. Lamport (chairman, subcommittee), W. D. Almy, E. L. Anderson, T. A. Blair, B. Bristow, C. B. Bronson, B. Chappell, L. S. Crane, J. C. DeJarnette, J. K. Gloster, J. L. Gressitt, S. R. Hursh, J. C. Jacobs, N. W. Kopp, Ray McBrian, B. R. Meyers, E. E. Oviatt, R. E. Patterson, R. B. Rhode, E. F. Salisbury, A. A. Shillander, W. D. Simpson, A. P. Talbot, R. P. Winton, Edward Wise, Jr., J. E. Yewell.

This is a progress report, submitted as information.

The subject matter contained herein covers principally the work of the Research Center staff of the Engineering Division, AAR, under direction of G. M. Magee, in studying rail joint gaps at high and low temperatures at test locations on the Pennsylvania Railroad near Hanna, Ind., and on the Chicago & North Western Railway near Calamus, Ia. (Appendix 10–a) ; and in performing tests of rail joint impact effects on the North Western near Clinton, Ia. (Appendix 10–b).

Installations of 78-Ft Rail

Following are listed the known installations of 78-ft rail on American railroads, exclusive of short stretches through highway crossings, along station platforms, over ballast-deck bridges, etc.:

Miles Laid by Years

1937 to 1951	*1952*	*1953*	*1954*	*1955*
52.9	20.2	62.2	107.5	108.7

Miles Laid by Railroads

Central Railroad of New Jersey	8.0
Chicago & North Western	66.7
Chicago, Burlington & Quincy	236.7
Grand Trunk Western	5.1
Kansas City Southern	1.0
Louisiana & Arkansas	10.0
Minneapolis, St. Paul & Sault Ste. Marie	20.0
Pennsylvania	3.0
Union Pacific	1.0
	351.5

Appendix 10–a

Joint Gap Measurements

Joint gap measurements were made at low temperatures in winter and high temperatures in summer on the 2 test installations of 78-ft rail that are being studied by the research staff for the subcommittee. One test installation is on 133 RE rail on the Pennsylvania Railroad near Hanna, Ind., consisting of 1 mile of 39-ft rail and 1 mile of 78-ft rail, and the other test installation is on 115 RE rail on the Chicago & North Western Railway near Calamus, Ia., also consisting of 1 mile of 39-ft rail and 1 mile of 78-ft rail. Previously reports of joint bar wear or pull in, joint droop, and profiles over the joints have been furnished the subcommittee on both of these test installations.

The measurements obtained in the PRR installations are shown in Fig. 1. Summer measurements were made in June 1953 with the rail temperature varying between 91 and 108 deg. The winter measurements were made in January 1954 with the rail temperature varying from — 1 to 3 deg. The summer measurements were not made at the maximum rail temperatures that may develop during the very hottest weather at this locality. It will be noted that there was considerable joint gap, which varied in amount from joint to joint, ranging from zero up to somewhat more than the full expansion opening of ⅜ in that is permitted by the difference in the diameter of the bolt and the rail drilling and joint bar punching. The measurements made in winter were down pretty close to the lowest rail temperature that would exist in this locality. The average joint gap opening was somewhat greater on the 78-ft rail than on the 39-ft rail, although not nearly in proportion to the increased rail length. Here again there was great variation in the amount of joint gap at individual joints, also varying from zero up to about ½ in as a maximum. There was a considerably higher percentage of the joints with the joint gap greater than ⅜ in on the 78-ft rail than on the 39-ft rail, but there were only a relatively few beyond 0.44 in, and it does not appear that the condition of maximum joint gap as it would affect bending of the bolts is too objectionable in this test installation.

The results of the measurements obtained on the 115 RE tests on the C&NW are shown in Fig. 2. The summer measurements were made in June 1954, with the rail temperature varying between 98 and 106 deg. It will be noted that on both the 39-ft and 78-ft rail the joint gap openings ranged from zero to about ½ in, with an average joint gap at this temperature ranging between 0.15 and 0.19 in. The winter measurements were made in February 1955 at a rail temperature varying from — 8 to — 10 deg, which is very close to the coldest rail temperature that would be expected in this locality. The average joint gap opening on the 39-ft rail was 0.22 and 0.29 in on the south and north rail, respectively, and for the 78-ft rail it was 0.43 and 0.39 in on the south and north rail, respectively. The variation in joint gap at individual joints ranged from zero to about ¾ in on the 39-ft rail and from zero to ⅞ in on the 78-ft rail. On both the 39-ft and the 78-ft rail there were a relatively small percentage of the joints with joint gap sufficiently greater than ⅜ in to indicate considerable bending of the bolts. The measurements obtained on these two tests make it possible to analyze the expansion and contraction action with regard to temperature change, and afford information of value regarding the ideal conditions for laying 78-ft rail in order to obtain most favorable joint gap openings.

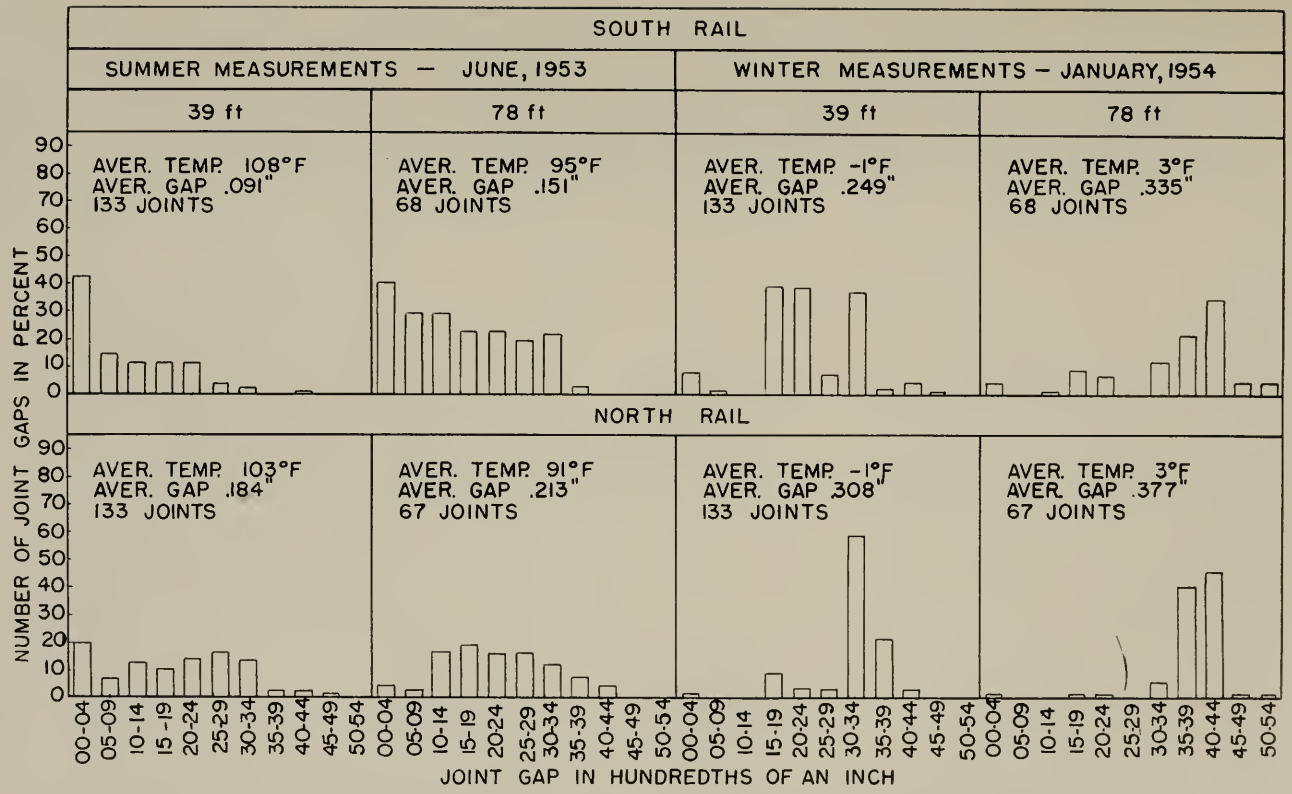


FIG. 1 JOINT GAP MEASUREMENTS FOR 39 ft AND 78 ft RAIL
PENN RR, MP 400-402, HANNA, INDIANA

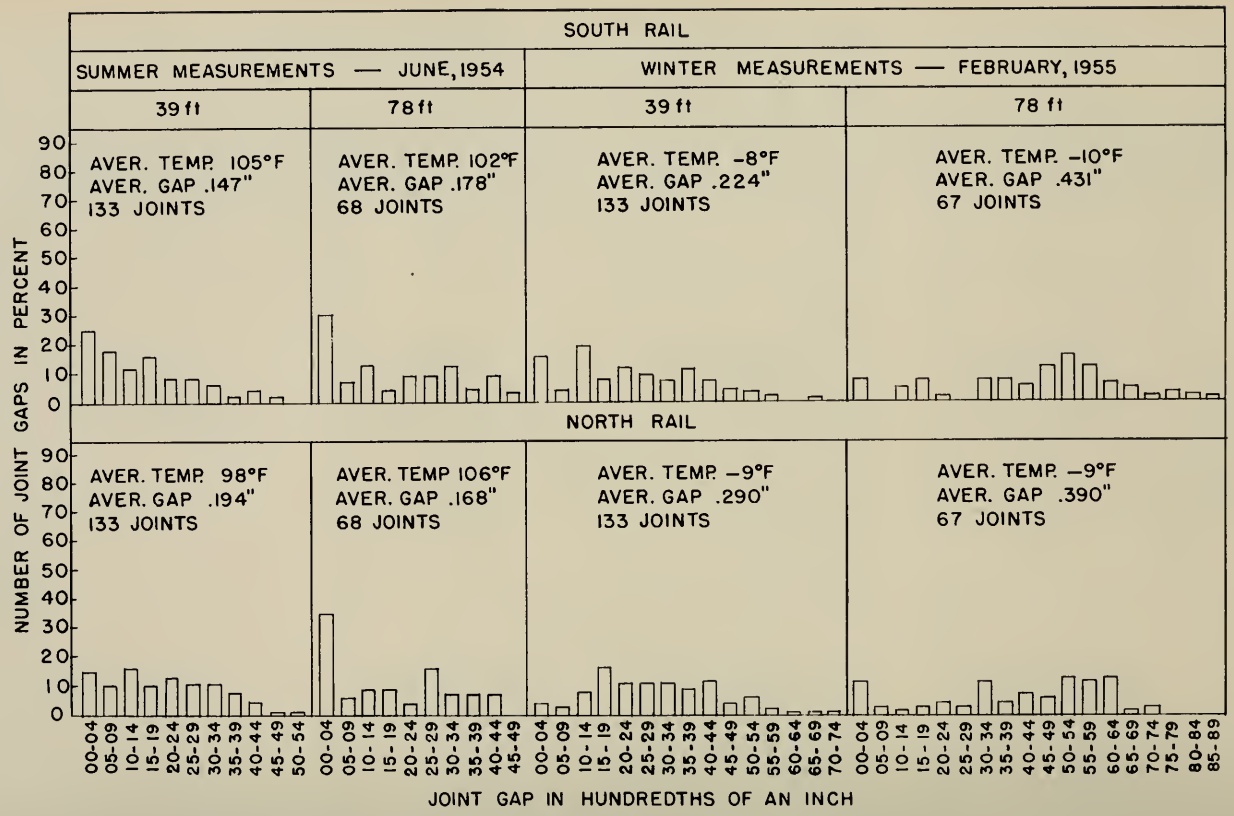


FIG. 2. JOINT GAP MEASUREMENTS FOR 39ft AND 78ft 115RE RAIL
C&NW RR, MPs 28-29 AND 32-33, CALAMUS, IOWA

Theoretical Considerations Regarding Expansion Movements of 78-ft Rail

The force required to restrain the expansion movement of 115 RE rail to 1 deg temperature change is equal to 0.0000065 × 30,000,000 × 11.25, or 2200 lb. Laboratory tests have shown that the slippage resistance of rail ends within a rail joint for applied bolt tension of 20,000 to 25,000 lb is equal to approximately 75,000 lb. Therefore, taking into account some small additional resistance from rail anchors, tie plates and spikes, it may be considered that the resistance offered by joint bars to rail end movements is sufficient to prevent any change in joint gap throughout a temperature change of 35 deg increase or decrease, or a total of about 70 deg.

Without any restraint, a 78-ft rail would change in length 0.375 in (maximum joint gap opening without bending the bolts) with a temperature change of 62 deg.

Therefore, for ideal conditions in a climate where the lowest rail temperature is — 10 deg, no rail should be laid when the rail temperature is below 25 deg. Rail should be laid with 0.375-in joint gap at this temperature and tight at 25 deg + 62 deg, or 87 deg. For intervening temperatures the following shims should be used:

Rail Temperature Deg	*Exp. Shim Inches*
87	0
77	1/16
66	1/8
56	3/16
46	1/4
35	5/16
25	3/8

No rail should be laid when the rail temperature is above about 90 deg, and this is important. Otherwise, joint gaps will be excessive in winter with bending of the track bolts and probably some breakage and pull aparts.

The accompanying diagram, Fig. 3, illustrates the above. If 78-ft rail were laid in accordance with this practice, then the average joint gap opening at any particular rail

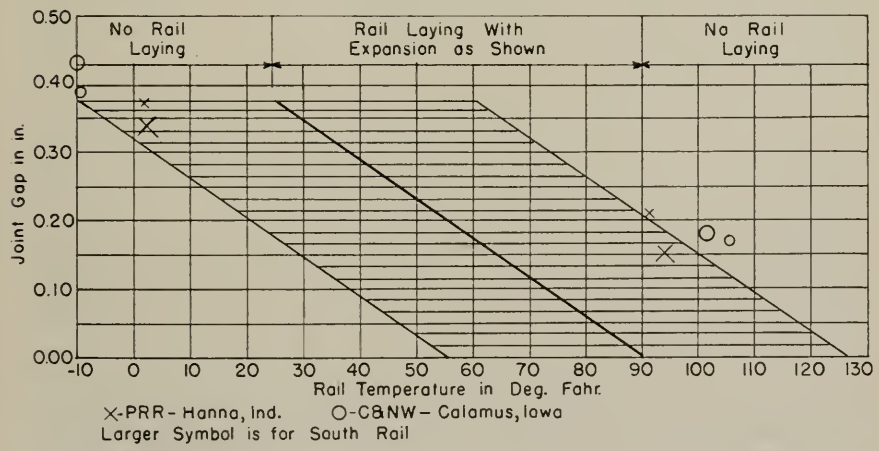


Fig. 3 Ideal Conditions For Joint Gap Openings With 78-Ft Rail.

temperature should fall within the shaded parallelogram or be on the zero line above 125 deg.

On Fig. 3 is shown the average joint gap measured in the 78-ft PRR test at Hanna during the winter and summer measurements for both north and south rails separately. The average measured joint gaps are indicated by the X's and it will be noted that all four values lie within the shaded area except one value which is only slightly outside. This indicates that the rail was laid reasonably near an ideal temperature-joint gap condition—that for the south rail being somewhat better than for the north rail.

The average joint gap opening for the 78-ft 115 RE test on the C&NW near Calamus are shown on Fig. 3 by circles, and it will be noted that this rail has about $\frac{1}{16}$ in too much joint gap for ideal conditions, all of the values being outside the parallelogram.

By comparing the measured change in joint gap between the summer and winter readings with the change that would have occurred if the rail were free to expand without restraint, the following values for joint restraint are indicated (it is assumed that the restraints from rail anchors, tie plates and spikes are negligible for this short a rail length):

	Joint Restraint in Each Direction	
PRR	*Lb*	*Equiv. Deg F*
39′ North rail	80,500	32
39′ South rail	72,500	29
78′ North rail	78,000	31
78′ South rail	79,000	31
C&NW		
39′ North rail	83,300	38
39′ South rail	96,500	44
78′ North rail	85,500	39
78′ South rail	77,700	35

It will be noted that these values of joint restraint in degrees agree reasonably well with the 35-deg value used in Fig. 3. The restraint for the 115 RE rail is somewhat more than 35 deg and that for the 133 RE rail somewhat less, due partly to the difference in rail cross section, and partly to the difference in slippage resistance (probably due to a somewhat higher bolt tension on the 115 RE test).

Practical Considerations

From a practical standpoint it is difficult to restrict the rail laying so no rail would be laid above 87 deg. Actually, however, this can be pretty well compensated for by laying rail with no expansion opening at temperatures below 87 deg. For example, when laying rail in the hot periods of the summer, and it is known that by noon the rail will be over 90 deg, the rail laid before noon when the rail temperatures are probably below 90 deg should be laid tight with no expansion allowed. This will help to prevent having too much expansion opening provided in the rail when it is laid. Rail anchors should be applied as the rail is laid to keep it from moving ahead towards the unrestrained end as it warms up during the day.

It will not be practical to utilize the full theoretical joint gap opening of $\frac{3}{8}$ in when laying rail because of difficulty in inserting the bolts. Actually, $\frac{1}{4}$ in is about the largest joint gap that can be used in laying, which would mean that rail should preferably not be laid at temperatures below 46. This is probably not a very important consideration for most rail laying.

Another practical difficulty is to obtain a uniform joint gap opening at all of the joints. Extensive experiments have been conducted with all types of rail lubricants in an effort to obtain uniform joint gap openings, but with very little success. The maintenance of as nearly uniform bolt tension as practical will, of course, be helpful. In any event, there is no reason to anticipate any greater difficulty with 78-ft rail in this respect than with 39-ft rail, and, in fact, the larger number of rail anchors per rail with the 78-ft rail should be beneficial in maintaining a more uniform distribution of expansion at the rail joints.

Acknowledgement

The Association is grateful to the Pennsylvania Railroad and the Chicago & North Western Railway for their contributions in making these tests possible.

Appendix 10–b

Tests of Rail Joint Impact Effects on the Chicago & North Western

These tests were conducted to obtain information that would be helpful in evaluating the economics of 78-ft rail. Fundamental information was obtained on the impact effects on joint ties due to rail end batter, joint gap, and joint bar fit of regular rail joints compared to the impact effects with a butt weld. The tests were conducted on the Chicago & North Western System westbound main line near Clinton, Ia., on October 26–30, 1952. The rail was 115 RE laid in 1949, and the joint bars were 36-in Rail Joint Company headfree K–4 bars.

A special test train was used consisting of a single diesel unit pulling a passenger car and three box cars equipped with high-speed trucks. The box cars were loaded with different weights so that the test included a diesel wheel load of 27,500 lb, a heavy car wheel load of 16,000 lb, a medium car wheel load of 12,300 lb, and an empty car wheel load of 7600 lb.

For each series of tests, runs were made at speeds of 5 to 90 mph. The tests included measurements of the loads on each joint tie, the tie accelerations on the receiving tie, and joint bar stresses or, in the case of butt welds, upper fillet and base stresses, at two joint locations. The test series was arranged to compare the effect of butt welds with both good and bad rail joint conditions. The most signficant information gained from the tests was as follows:

Impact Load on Joint Ties

The diesel wheels produced maximum tie loads, and the added load on the joint ties due to impact effects was found to be about the same with good rail joints having little batter and well fitting bars, as with butt welds, and was about 5 percent in magnitude. The impact effect at the butt welds was due to a slight irregularity in the running surface at the welds, presumably due to some inaccuracy in alinement of the rails and final grinding procedure. With poorly fitting joint bars and heavy rail end batter the impact effect was found to be as much as 60 percent. However, it was not possible to keep the joint ties firmly tamped up with the bad joint conditions, and the total tie load was only about 20 percent more with the bad joint condition than with the butt weld or good joint condition. For all wheel loads the added joint tie load due to impact effect was substantially the same quantitatively, irrespective of the amount of wheel load.

Accelerations of Joint Ties

The measured accelerations of the joint ties gave some unexpected results. They were found to increase directly with speed in almost a straight-line relation, and were substantially the same irrespective of the amount of wheel load. They reached some very high values and were about 15 to 20 *g* in magnitude at 90 mph with the butt weld and good joint conditions, and somewhat more than twice as much, or about 40 *g*, with the bad joint conditions at the same speed.

Joint Bar Stresses

The measured joint bar stresses were about twice as great with the bad joint condition as with the good joint condition, but were well within the strength of the bars.

Rail Stresses Near the Butt Weld

Both the vertical compression stresses in the upper rail web and the bending stresses in the base of the rail near the butt welds showed small but definite impact effects due to the surface irregularity under the diesel wheels. This might result in the development of some batter at the welds and requirements in the future for some grinding to maintain a sufficiently smooth running surface.

Conclusions

It may be concluded from the tests that an evaluation of the economic value of the butt weld versus a regular rail joint may be obtained by estimating the maintenance expenditure required to keep the rail end batter, fit of the joint bars, and bolt tension in substantially the same condition as that of the two good rail joints included in the tests. This would require welding or grinding to maintain the rail end batter not to exceed 0.015 in, replacement of bars to maintain a tight fishing fit, and the tightening of track bolts at least once yearly. The cost of rail joint lubrication or corrosion protection should also be included.

TEST PROCEDURE

Purpose of Tests

These tests were conducted to develop fundamental information regarding the added load that is placed on joint ties at rail joints specifically as related to the amount of rail batter, joint gap, and joint bar wear. It was considered this information would be helpful in appraising the economics of 78-ft rail which would eliminate these added impact loads at one-half of the rail joints.

Test Location and Track

A convenient and suitable location for the test was selected on the double-track main line of the North Western at M. P. 131.3, about 6½ miles east of Clinton, Ia. All tests were conducted on the north rail of the westbound track during the week of October 26–30, 1952. The track structure consisted of 115 RE rail laid in 1949. The joint bars were 36-in, headfree, Rail Joint Company K–4 bars with center easement. The tie plates were 7¾ by 11-in, double shoulder, with a cant of 1 in 40 and an eccentricity of ⅜ in. The ties were 7 by 9-in creosoted oak. The ballast was crushed limestone. The condition of the track was good.

Instrumentation

Two representative rail joints were selected for the tests on the north rail of the westbound track, spaced 78 ft apart. These were both suspended joints, with the two

ties of each joint an equal distance from the joint gap. These two joints were designated location A and location B; the leaving ties were designated A_1 and B_1, respectively, and the receiving ties A_2 and B_2, respectively. In order to determine the tie loads and impact loads at each of these four joint ties, three ½-in SR–4 wire resistance gages were attached to the underside of each of the four tie plates, along the center line lengthwise of the tie plate. One of these gages was placed under each edge of the rail base, and the third gage was placed under the middle of the rail. Previous tests had shown that gages so placed could be depended upon to measure reliably the load applied by the tie plate to the tie. After the field tests were completed, these stress-recording tie plates, still attached to the original ties, were brought into the laboratory for stress-load calibration so the tie plate stresses recorded in the field tests could be converted to loads applied on these ties in the track by the test train wheels.

In addition to measuring the load, including impact effect, applied to these four joint ties, the rate of acceleration due to impact effect was also measured on the two receiving ties, A_2 and B_2, by means of an accelerometer attached to each of the two ties just beyond the field end of the tie plate, approximately 11 in from the center line of the rail. Statham accelerometers were used which were accurate to accelerations up to at least 200 *g* and frequencies up to 700 cycles per second. These accelerometers were placed to measure the tie acceleration and vibration in the vertical direction.

Also, at each of the two joints, ¼-in SR–4 wire resistance gages were attached to the tops and bottoms of the inner and outer joint bars at their mid-length. The top gages were located 0.75 in inside and above the top outer flange of the bars, and the bottom gages were located on the outer bottom flange 0.40 in above the bottom extreme fiber. These gage measurements were indicative of the flexural stress and bending moments developed in the bars during the test runs.

For the runs with the butt weld replacing the rail joints, measurements of vertical web stresses and longitudinal bending stresses in the base were made with four ¼-in SR–4 gages attached to the rail 1 in from the butt weld. Two of these gages were located vertically on the upper part of the inner and outer web faces near the fillet at gage locations 3 and 13 (see AREA Proceedings, Vol. 47, 1946, page 454). The other two gages were located longitudinally on the top inner and outer flanges of the rail base, ¼ in inside the upper corners at gage locations 9 and 19. The stresses at gage locations 3 and 13 in previous tests have been found to be indicative of the amount of wheel load and eccentricity of loading. Gage locations 9 and 19 are indicative of the flexural bending stress developed in the rail.

The 10 stress gages and 1 accelerometer for joint A were recorded simultaneously on oscillograph A, and those for Joint B were recorded simultaneously on oscillograph B.

Test Train

In order to afford a reliable comparison of the various track conditions being studied it was necessary to make test measurements under exactly the same wheel loads throughout the test. It was also necessary to secure measurements throughout the entire range of speed that would be encountered in ordinary operation. These two requirements made it necessary to use a special test train for all the tests.

The test train consisted of C&NW diesel unit 5018B (6–6), pulling 3 box cars of C&NW 68,000 class equipped with high-speed trucks, and a passenger car. The diesel unit had 36-in diameter wheels and a wheel load of 27,500 lb. The box cars had 33-in wheels and 1 was heavily loaded, the second was half loaded, and the third was left

empty, thereby providing wheel loads of 16,000, 12,300 and 7600, respectively. For each series of tests at least 2 test runs were made at each of the following speeds: 5, 10, 20, 30, 50, 70 and 90 mph.

On the oscillograms only values of the first wheel of the second truck of the diesel unit and the three cars were read and plotted.

Schedule of Tests

The tests schedule was arranged so that tie loads and accelerations would be determined for what would be considered a good rail joint condition on the one hand, and the worst rail joint condition that would normally be expected in the main line track on the other hand, compared with the tie loads and accelerations that would exist if the rail were continuous with no rail joint present. This was accomplished by the following five test conditions at both joint locations A and B:

Series 1, rail joint with little batter, 15,000-lb bolt tension and zero joint gap.
Series 2, rail joint with little batter, 15,000-lb bolt tension and $\frac{3}{8}$-in joint gap.
Series 3, butt weld replacing rail joint.
Series 4, rail joint with heavy batter, simulated joint wear and zero joint gap.
Series 5, rail joint with heavy batter, simulated joint bar wear and $\frac{3}{8}$-in joint gap.

For the rail ends of series 4 and 5 a batter of about 0.060 in was ground at joints A and B, as shown in Fig. 1. The ground batter was started at about 4 in from the leaving rail end and extended to about 5 in beyond the receiving rail end. This ground batter simulated heavy batter that develops in service according to results obtained in the service tests of various types of joint bars, 1937–1947. In these tests on both the Santa Fe and Pennsylvania, after 10 years of service, the measured rail end batter on end-hardened rail averaged about 0.020 in and on non-end hardened rail about 0.042 in, not including a general drooping of the rail surface across the rail joints.

The batter was not measured on the good joint condition included in series 1 and 2, but the rail was end hardened and had been in service only about 3 years at the time of the tests and the joint condition was representative of the best maintenance condition.

For the tests in series 3 it was desired to eliminate the joints at locations A and B so a smooth running surface would be provided with no impact effects on the test ties. Since rolled 78-ft rails were not available, it was decided to use two 78-ft rails that had been formed by butt welding 39-ft rails together. It was found that the butt welds did not provide as smooth a running surface as was anticipated. The rail surface profiles across the butt welds at locations A and B are also shown in Fig. 1.

For the weld at location A the rail surface profile was high by about 0.060 in. in a span of 40 in, and there is a depression of about 0.020 in at the weld, the depression extending over a length of about 10 in. The rail surface profile for the weld at location B was high by about 0.020 in. in a span of 40 in,and there was only a slight depression at the weld. According to measurements made on other pressure welds of the same type at other locations the irregularity in rail surface profile at location A represents about the extreme condition that would normally be encountered, whereas the rail surface profile at location B may be considered as good.

The ties adjoining the two test joints were tamped before the test was started and at times during the test when it was thought that there might be any track play. In addition, thin steel shims were inserted between the rail and tie plates at several ties each way from the test joints to shim out the track play and have a uniform rail support at the test ties and for several ties each way therefrom.

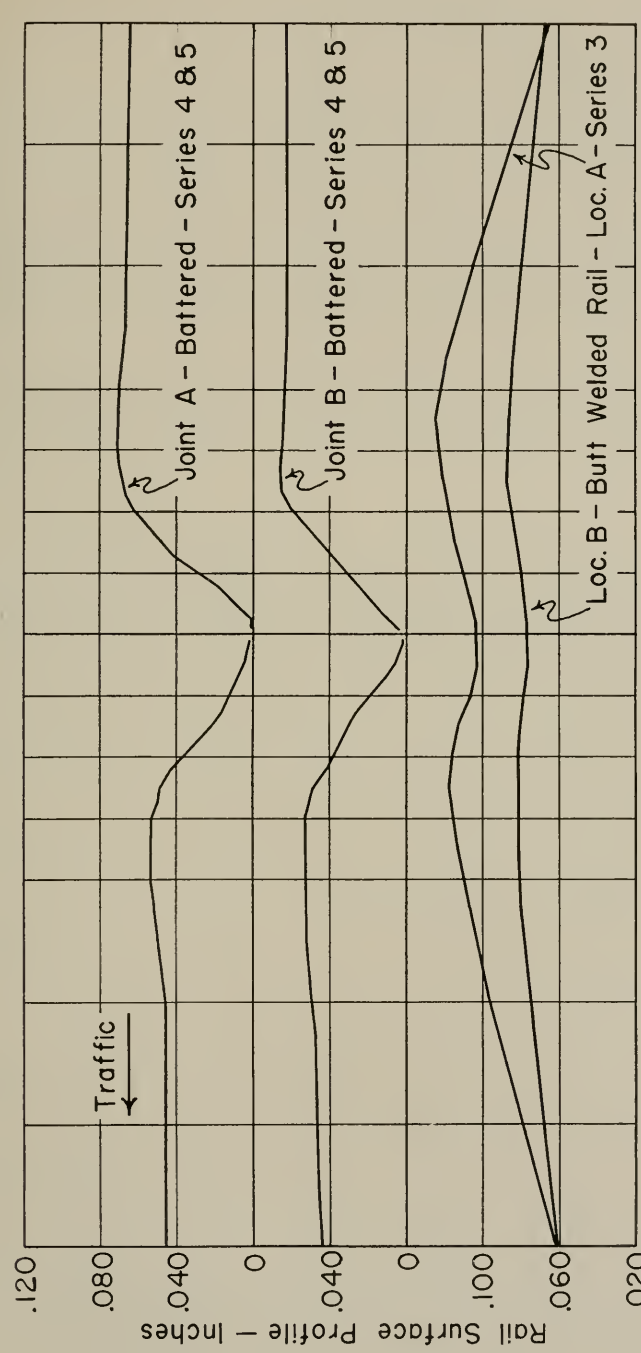

Joint A – Battered – Series 4 & 5
Joint B – Battered – Series 4 & 5
Loc. B – Butt Welded Rail – Loc. A – Series 3
Traffic
Rail Surface Profile – Inches
.120
.080
.040
0
.040
0
.100
.060
.020
20 16 12 8 6 4 2 0 2 4 6 8 12 16 20
Distance from Rail Ends or Weld – Inches

Fig. 1 – Rail Surface Profiles Across Test Rail Ends – Series 3, 4 and 5.

RESULTS OF TESTS

Impact Load on Joint Ties

To afford a better understanding of the manner in which the loads were applied to the test ties and the impact characteristics, Fig. 2 is presented. This figure is a composite of the stress oscillograms for one of the three stress gages on tie plate B_1 (on a leaving joint tie). Only that portion of the oscillograms from about the middle of the diesel unit to the middle of the heavy test car is reproduced. The first diesel wheel of the rear truck, marked 4 on the figure, was the wheel under which all diesel wheel readings were measured from the records. Oscillograms are given for speeds of 5 and 90 mph at location B for series 1—a good joint with little joint batter, tight bolts and zero joint gap; series 3—a butt weld; and series 4—a heavily battered joint with loose bolts and zero joint gap.

For the 5-mph speed of series 1, shown in Fig. 2, it will be noted that when wheel 4 approaches to within about 100 in of the recording tie, the tie starts to receive load, and that a continuous load is applied to the tie until after wheel 2 has passed. The profile

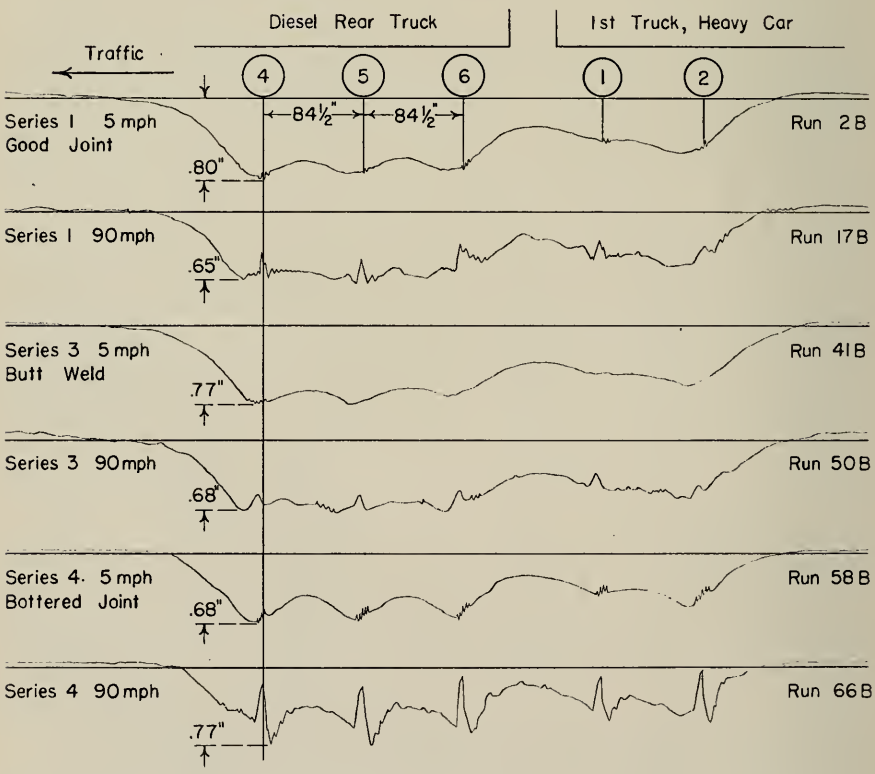


Fig. 2 - Stress Oscillograms for Tie Plate B_1 which are Proportional to Tie Load on Leaving Joint Tie at Speeds of 5 and 90 mph for a Good Joint, a Butt Weld and a Battered Joint.

of this tie pressure curve corresponds closely to the profile of the theorectical curve of intensity of pressure against the rail from the Master Diagram, AREA Proceedings, Vol. 35, 1934, page 180, for a combination of the five wheels shown at the top of Fig. 2. From the plate stress curves at 5 mph for series 1 and 3 it can be observed that there is practically no impact on the tie as each wheel crosses the joint or weld. At the slow speed for series 4, with the heavily battered joint, there is a small impact on the tie and a lessening of tie load as the wheels cross the joint.

At the 90-mph speed for series 1 and 3, as each wheel passes over the joint, as shown in Fig. 2, there is an almost instantaneous release of tie load, but this is not followed by a greater tie load than just before the wheel crossed the middle of the joint. It can be seen that the release of tie load at the 90-mph speed as the wheels cross the weld of series 3 is considerably less than the release of load as the same wheels cross the good joint of series 1. At the 90-mph speed for series 4, with the heavily battered joint, as each of the 5 wheels passd over the middle of the joint there was an instantaneous release of 75 to 100 percent of the load. This instantaneous release of load was followed immediately by an impact that produced an increase of tie load to an amount considerably greater than the load on the tie just before the wheel reached the middle of the joint.

Fig. 3 gives the average measured tie load under 1 rail at speeds of 5 to 90 mph for the ties of joints A and B for all 5 test series. For series 1, 2 and 3, which included the two good joint conditions and the butt weld, the average joint tie loads under the diesel wheel were a maximum at a speed of 10 to 20 mph, and gradually lessened until at the 90-mph speeds the tie loads were about 83 percent as great as at the slow speeds. From the bar graphs in the upper left portion of the figure it can also be seen that the average tie loads for series 1, 2 and 3, at 5 mph, are almost as great as the maximum tie loads produced at any speed. For the same three series, the average joint tie loads under the heavy, medium and light car wheel loads were almost constant for all speeds from 5 to 90 mph. The only variance from this condition was for the heavy car over the butt weld at a speed of 50 mph, at which speed, for some unknown reason, the tie loads were somewhat higher than at other speeds. The rail surface profile at the butt weld at location B was high by about 0.020 in. in 40 in, while the profile at location A was high by about 0.060 in (see Fig. 1). However, these tie loads acted in general the same manner under the two welds, and the weld with the higher profile did not increase the tie loads at the higher speeds.

Fig. 3 also shows the tie loads for series 4 and 5 having the bad joint conditions with heavily ground rail end batter and low bolt tensions, and with rail joint gaps of 0 in and 3/8 in. The average tie loads under the diesel wheels at 5 mph were about 22 percent less than for the good conditions of series 1, 2 and 3, but at an intermediate speed the tie loads increased 51 and 60 percent, respectively, under the diesel wheel. For the heavy, medium and light car wheels the tie load at the 5-mph speed was considerably less than for the same loads for series 1, 2 and 3, but these tie loads more than doubled at an intermediate speed.

The tie loading conditions of series 5, with the rail gap increased from 0 to 3/8 in, shows considerably more tie load and impact at speeds of 30 mph and above than for series 4 with zero rail gap. The bar graphs at the left side of Fig. 3 show that for series 4 and 5 the maximum tie loads at an intermediate speed average 6500 lb more for the diesel, heavy and medium car wheels than the tie load at 5 mph. This figure shows that the tie loading conditions for the badly battered joints, with their high impact effects,

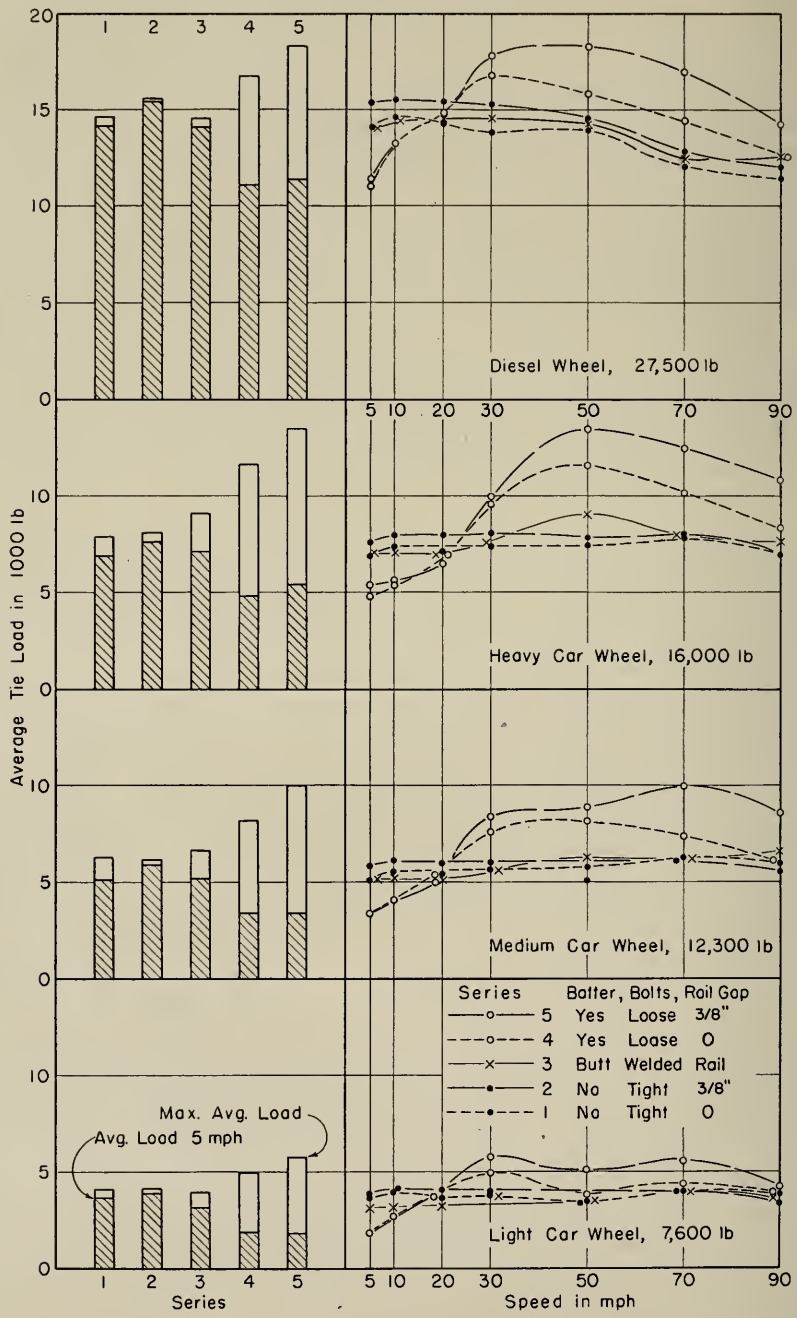

Average Tie Load in 1000 lb
Diesel Wheel, 27,500 lb
Heavy Car Wheel, 16,000 lb
Medium Car Wheel, 12,300 lb
Light Car Wheel, 7,600 lb
Series Batter, Bolts, Rail Gap
5 Yes Loose 3/8"
4 Yes Loose 0
3 Butt Welded Rail
2 No Tight 3/8"
1 No Tight 0
Max. Avg. Load
Avg. Load 5 mph
Series
Speed in mph

Fig. 3 – Average Tie Loads at Speeds of 5 to 90 mph at Joint A Tie A_1, A_2 and Joint B Tie B_1, B_2.

are far from being satisfactory, and that had these conditions been allowed to remain in track it is undoubtedly true that they would have become progressively worse. The figure also shows that for the badly battered joints the maximum tie loads and impact effects for all wheel weights occur at speeds of 30, 50 or 70 mph, and always reduce at the 90-mph speed.

Table 1 is presented to show the same tie load data as presented in Fig. 3, but in different form. In the top portion of the table the ratio of maximum impact tie load to the load at 5 mph is given. The speed for the individual maximum ratio is given to the right of the ratio, in parenthesis. In the left portion of the table, the average data for ties A_1, A_2, B_1 and B_2 are given. In the middle and the right-hand portion of the table, the data are divided into the averages of the receiving and leaving ties of joints A and B. While there are some differences in the ratios between the receiving and leaving joint ties they cannot be considered significant. In the lower portion of the table the maximum increase in tie load, in 1000 lb, due to impact above the load at 5 mph, is given. It is seen that the maximum increase in tie load for the good conditions of series 1, 2 and 3 is small, and that the increase for the heavily battered conditions of series 4 and 5 is large.

The average joint tie load at 5 mph reported in Fig. 3 under the 27,500-lb diesel wheel for the 5 series ranged from 11,100 to 15,400 lb under 1 rail. These joint tie loads are considerably higher than the theoretical tie loads, assuming the modulus of the track to be 2000 lb per in and a tie spacing of 21 in. With the diesel wheel directly over the rail joint, the calculated load at 5 mph on the leaving joint tie should be 7000 lb and on the receiving tie 6100 lb, assuming that every tie along the track takes its proportionate share of load, as shown in the Master Diagram. The ties in the track near the test joints were kept well tamped up and shimmed throughout the test, which could account for a somewhat higher measured average joint tie load than calculated. When the individual ties and tie plates were stress-load calibrated in the laboratory it is also possible that the tie plate seats on the ties were disturbed enough to cause a somewhat higher load in the laboratory for a given tie plate stress than actually occurred in the track. However, it is thought that the data presented in Fig. 3 are representative of the pattern of tie loading actually existing in track throughout the speed range, even if the reported tie loads in pounds are somewhat higher than normally existed.

Throughout the tests, receiving tie B_2 produced loads about one-half as large as the other three joint ties. Joint ties A_1, A_2 and B_1 produced high loads of the same magnitude.

Accelerations of Joint Ties

As previously stated, accelerometers were attached to the tops of receiving joint ties A_2 and B_2 to record the accelerations in a vertical direction, both downward and upward. Average downward accelerations of the ties for one wheel of the diesel, and heavy, medium and light cars, are plotted separately in terms of g for speeds of 5 to 90 mph in Fig. 4. The first observation to be made of the figure is that the pattern of tie accelerations for any given series is almost the same for each of the four wheels, regardless of wheel weight. Such variations from this pattern as are indicated do not appear to be significant. The second observation to be made is that, in general, the tie accelerations increase in almost a straight line with increase in speed. The third observation is that there is a considerable difference in the magnitude of the accelerations for the bad joint conditions compared to the good joint conditions and the butt weld.

TABLE 1 - Ratio of Maximum Impact Tie Load to Load at 5 mph and Maximum Increase in Impact Tie Load in 1000 lb above Load at 5 mph - Ties at Joints A and B - Speeds 5 to 90 mph.

Wheel Load	Average of Ties A_1 A_2 B_1 B_2 Joints A and B					Average of Receiving Ties A_2 B_2 Joints A and B					Average of Leaving Ties A_1 B_1* Joints A and B				
	Series					Series					Series				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Ratio of Maximum Tie Load to Load at 5 mph														
Diesel	1.03(10)	1.01(10)	1.03(30)	1.51(30)	1.60(50)	1.09(20)	1.11(30)	1.08(30)	1.80(30)	1.93(50)	1.03(10)	1.00(5)	1.01(10)	1.30(30)	1.40(50)
Heavy Car	1.15(70)	1.06(30)	1.28(50)	2.42(50)	2.50(50)	1.32(70)	1.19(70)	1.33(50)	3.14(50)	3.24(50)	1.08(10)	1.08(10)	1.26(50)	2.00(50)	2.18(70)
Medium Car	1.23(70)	1.05(10)	1.29(90)	2.41(50)	2.94(70)	1.37(70)	1.07(70)	1.18(50)	3.08(50)	3.50(70)	1.19(70)	1.05(10)	1.25(50)	2.09(50)	2.74(70)
Light Car	1.11(70)	1.08(10)	1.40(70)	2.63(30)	3.22(30)	1.45(90)	1.35(70)	1.54(70)	4.09(30)	4.45(30)	1.09(10)	1.11(10)	1.42(70)	2.08(30)	2.84(70)
	Maximum Increase in Tie Load in 1000 lb. above Load at 5 mph														
Diesel	0.5(10)	0.2(10)	0.5(30)	5.7(30)	6.9(50)	0.8(20)	1.2(30)	0.7(30)	7.0(30)	8.3(50)	0.6(10)	0.0(5)	0.1(10)	4.1(30)	5.5(50)
Heavy Car	1.0(70)	0.5(30)	2.0(50)	6.8(50)	8.1(50)	1.3(70)	1.0(70)	1.3(50)	7.5(50)	8.5(50)	0.8(10)	0.8(10)	2.7(50)	6.1(50)	8.0(70)
Medium Car	1.2(70)	0.3(10)	1.5(90)	4.8(50)	6.6(70)	0.9(70)	0.3(70)	0.5(50)	4.8(50)	5.5(70)	1.4(70)	0.4(10)	1.9(50)	4.9(50)	7.8(70)
Light Car	0.4(70)	0.3(10)	1.3(70)	3.1(30)	4.0(30)	0.9(90)	0.8(70)	0.7(70)	3.4(30)	3.8(30)	0.5(10)	0.6(10)	2.1(70)	2.9(30)	4.4(70)
Avg. Max.	0.8	0.3	1.3	5.1	6.4	1.0	0.8	0.8	5.7	6.5	0.8	0.5	1.7	4.5	6.4

(30) Speed for Maximum Tie Load

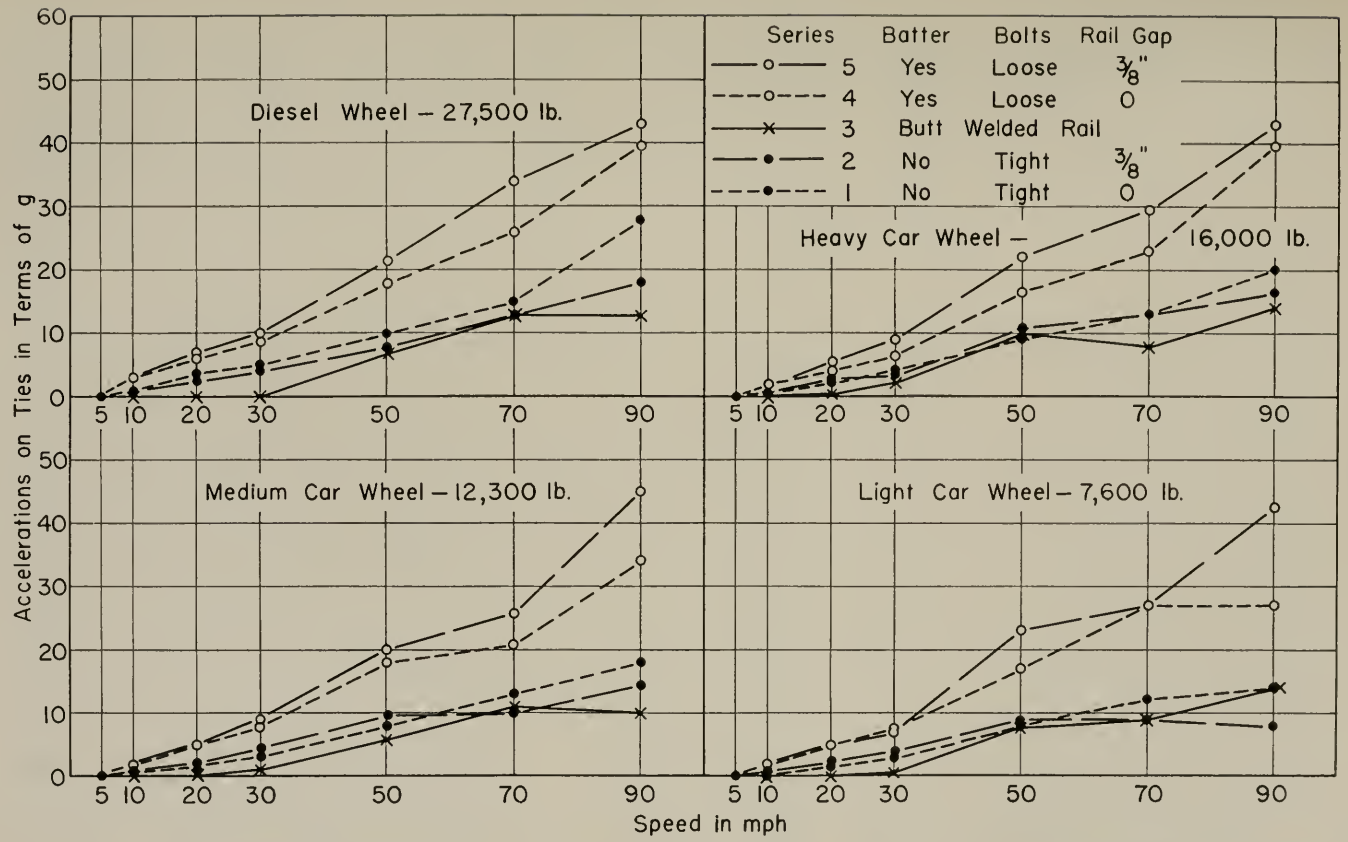

Series Batter Bolts Rail Gap
5 Yes Loose 3/8"
4 Yes Loose 0
3 Butt Welded Rail
2 No Tight 3/8"
1 No Tight 0
Diesel Wheel – 27,500 lb.
Heavy Car Wheel – 16,000 lb.
Medium Car Wheel – 12,300 lb.
Light Car Wheel – 7,600 lb.
Accelerations on Ties in Terms of g
Speed in mph
0 10 20 30 40 50 60
5 10 20 30 50 70 90

Fig. 4 – Average Acceleration on Receiving Ties A_2, B_2 of Joints A and B at Speeds of 5 to 90 mph.

Throughout the speed range included in the test the measured accelerations are somewhat more than twice as much for the bad joint conditions of series 4 and 5 as they are for the good joint conditions of series 1 and 2 and the butt weld of series 3. The fourth observation is that the measured tie accelerations at the high speeds reached rather considerable magnitudes. For the bad joint conditions the accelerations at 90 mph were on the order of 40 *g*, and for the good joint conditions on the order of 15 to 20 *g*. The measured accelerations in series 5 with bad joint conditions and 3/8-in joint gap were somewhat greater than for the same joint conditions, but with no joint gap. On the other hand, with the good joint conditions the measured accelerations were slightly higher in series 1 with no joint gap than in series 2 with 3/8-in joint gap, especially under the diesel wheel. It seems likely that the difference between series 1 and 2 does not reflect the difference in joint gap but other conditions, probably that of some slight difference in play in the ties between these two series.

It is quite surprising to find that the tie accelerations in terms of *g* at any speed are as great for the light wheel loads as for the heavy wheel loads. Accelerations are difficult to measure and usually acceleration data are rather variable and ordinarily do not fit into a consistent and moderately uniform pattern. However, the tie acceleration data obtained in this test give every indication of a rational pattern.

The rate of acceleration of the mass of the tie is directly proportional to the external forces acting upon it. The forces required to produce the acceleration of 40 *g* measured at 90 mph may be obtained from the equation:

$$F = Ma = \frac{W}{g} a$$

in which F is the force in pounds;

M is the mass of one-half of the tie equal to $\frac{W}{g}$;

W is the weight of one-half of a creosoted oak tie in pounds;

a is the measured acceleration of the tie in feet per second per second;

g is the acceleration of gravity, which is 32.2 feet per second per second.

Substituting in this equation 100 lb as one-half the weight of a creosoted oak tie and 40 *g* for the measured acceleration, it is determined that a force of 4000 lb would be required to produce the acceleration of the tie which was recorded in the tests at 90 mph. In these tests only the one external force applied to the tie by the tie plate was measured. The other external forces acting on the tie are the reactive pressure from the ballast and perhaps some resisting bending moment from the other one-half of the tie. Neither of these latter two was measured in the tests. It is of interest to note, however, that in Fig. 3 the measured increase in tie load due to impact effects for the light car wheels at 90 mph in series 5 were on the order of 4000 lb, which would indicate that almost the entire impact force applied by the tie plate to the tie under the light car wheels was required to produce the rate of acceleration that was recorded.

Just what significance or importance may be attached to the rate of acceleration of a tie with respect to stability of the track structure or wear of its component parts is not known at the present time. However, it does appear that the lower measured tie accelerations obtained in series 1, 2 and 3 with the good joint conditions could be expected to be indicative of considerable reduction in track surfacing costs at the joints, and perhaps also of reduced shattering of the ties.

Frequency of Tie Accelerations

The frequency of the vertical accelerations of the receiving ties were found to vary with increase in train speed. Typical sketches are shown in Fig. 5 for runs of series 5 having heavily battered rail ends, loose bolts, and ⅜-in joint gap. For the 5-mph speed no measurable accelerations were recorded. For the speeds of 10, 20 and 30 mph the tie accelerations were low and the frequency of the main downward acceleration was about 100 cycles per second. For the 10-mph runs there was one downward tie acceleration as a wheel impact from the battered joint occurred and no other tie acceleration whatsoever in either the downward or upward direction. For the 20-mph runs the main downward tie accelerations under most wheels was followed by one minor upward acceleration at about 100 cps frequency. For the 30 and 50-mph runs at most wheels a small upward acceleration preceded the main downward impact acceleration, and following it there were 2 minor upward accelerations, all spaced at about 100-cps frequencies for the 30 mph runs and at about 200-cps frequencies for the 50-mph runs. For the 70 and 90-mph runs under most wheels a small upward acceleration preceded the main downward tie impact and this was followed by a considerable size upward (sometimes as great as three-quarter of the main downward acceleration), then downward, then upward acceleration, all at frequencies from 300 to 400 cycles per second for the 70-mph speed, and from 400 to 500 cycles per second for the 90-mph speed.

Some of the diesel and car wheels other than the four wheels analyzed throughout all the tests, occasionally produced tie accelerations considerably greater than the four wheels discussed. In Fig. 5 the upward, or negative, tie acceleration at 90 mph is shown to reach three-quarters as much as the maximum downward acceleration. No corresponding decrease in tie load is shown in Fig. 2, which indicates that with the wheel rebound, the wheel, rail and tie are moving pretty much together, with little change in tie plate load. The decrease in tie load (Fig. 2) occurs while a wheel is jumping from the leaving to the receiving rail end, and ½ cycle in frequency before the maximum downward tie acceleration (Fig. 5) occurs.

On all tie acceleration oscillograms of series 5 for speeds of 30 to 90 mph, when any portion of the test train was over the tie accelerometer, there was a continuous but minor high frequency vibration in both the downward and upward directions amounting to less than 1 g. These minor vibrations have a frequency at speeds which appear from only a superficial study to be of exactly the same frequencies as the major impact acceleration frequencies directly under the wheels described above, namely about 100 cycles per second at the 30-mph test train speed, 200 cycles per second at 50 mph, 300 to 400 cycles per second at 70 mph, and 400 to 500 cycles per second at 90 mph. These minor accelerations are not shown in Fig. 5 superimposed on the major frequencies. In fact, the tie plate and joint bar high-speed stress oscillograms have a continuous minor stress vibration superimposed on them when the wheels are within 5 ft of the recording gage. At any train speed of 30 mph or above, the frequencies of these minor stress vibrations are at or about the same high frequencies as the minor tie acceleration vibrations described above. These minor vibrations are a characteristic of the track or wheels and not a natural frequency period of any of the recording apparatus.

The frequencies of the major vertical accelerations of the ties for series 1, 2, 3 and 4 were not studied, but from superficial observations of the oscillograms it appears that the major and minor tie acceleration frequencies were about the same for the various speeds as reported above for series 5.

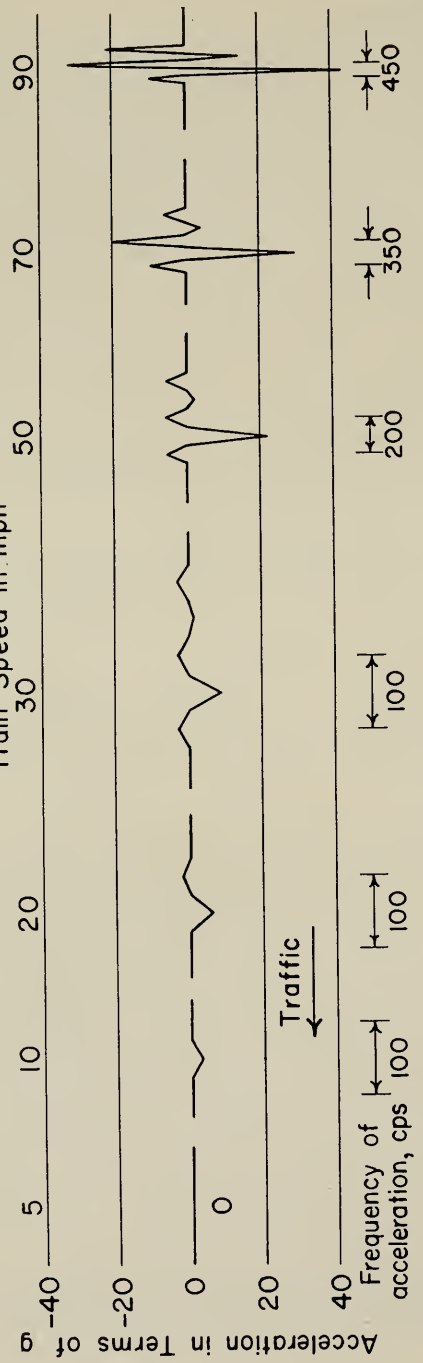


Fig. 5 — Typical Sketch of Tie Accelerations for Any One Wheel at Various Speeds — Series 5, Heavily Battered Rail Ends.

Joint Bar Stresses

For series 1, 2, 4 and 5 bending stresses were measured at mid-length on the tops and bottoms of both inner and outer bars of joints A and B.

As shown in Fig. 6 for series 1 and 2 having good joints without rail end batter, the average stress in the tops and bottoms of the joint bars under the diesel wheel were highest at the 5 and 10-mph speeds and of less magnitude at the higher speeds. The bar graphs at the left of Fig. 6 show that for any wheel there is little increase in bar stress for any condition at speeds greater than 5 mph. In no case does the average maximum bar stress exceed 10,300 psi. This is about one-half the calculated stress that would be developed by the diesel wheel in the bars, provided the bars carried the full bending moment across the joint. For the car wheels the bar stresses were low, and throughout the speed range there was little change.

Considerably higher stresses were developed in the joint bars under all wheels with the heavily battered conditions of series 4 and 5, especially at speeds of 10, 20 and 30 mph where the maximum average tensile stress reached 17,100 psi. As shown in Fig. 6, the joint bar stresses at the 5-mph speed were higher by from 1500 to 3500 psi for all wheels than for the good joint conditions. The increase in bar stress at the low intermediate speeds, due to the impact effect across the battered joints, also increased the stresses an additional 3000 to 5000 psi for the 4 wheel weights studied. For all wheels the top and bottom bar stresses for the battered joint conditions were less at the 90-mph speed than for the speed of 30 mph.

Stresses in Rail Near Weld

Series 3 was the condition with the butt welds at the middle of the 78-ft rail placed at track locations A and B. The vertical direct stress was measured on both faces of the upper web at gage locations 3 and 13, 1 in from the welds. Gages were also located longitudinally on the top inner and outer flanges of the rail base, ¼ in inside the upper edges, at gage locations 9 and 19.

Under the diesel wheel the average vertical direct compressive stress in the rail web, as shown at the top of Fig. 7, was 9400 psi at the 5-mph speed, and increased to 11,500 psi at the 20-mph speed, then decreased in an almost straight line to 6900 psi at the 90-mph speed. The measured direct stresses at the 5 to 20-mph speeds are of the same magnitude as have been recorded in former tests in ordinary rails on tangent track. For the car wheels the direct web stresses are of nearly constant values throughout the entire speed range.

In the top right portion of Fig. 7 for the diesel wheel only, the individual vertical stresses on both web faces are plotted to show the range of stress existing in the rail webs. The narrow range of scatter indicates that for all the test runs the centroid of pressure of the diesel wheel is quite close to the middle of the rail head. Even for the 30-mph run that produced 10,000 and 16,000 psi compression in the 2 web faces, the calculated centroid of the wheel pressure is less than 0.2 in inside the middle of the rail head.

The average longitudinal bending stresses measured at the two edges of the rail base near the butt welds are plotted in the lower portion of Fig. 7. Under the diesel wheel the stress increased slightly up to the 30-mph speed, then receded until the stress was less at the 70 and 90-mph speeds than at the low speed. These longitudinal stresses measured in the rail base near the butt weld at the low speed are about one-half the calculated stress for similar conditions in ordinary rail. This is consistent with the unusually high tie loads measured and indicates that the joint ties were relieving the rail of a normal bending moment over them.

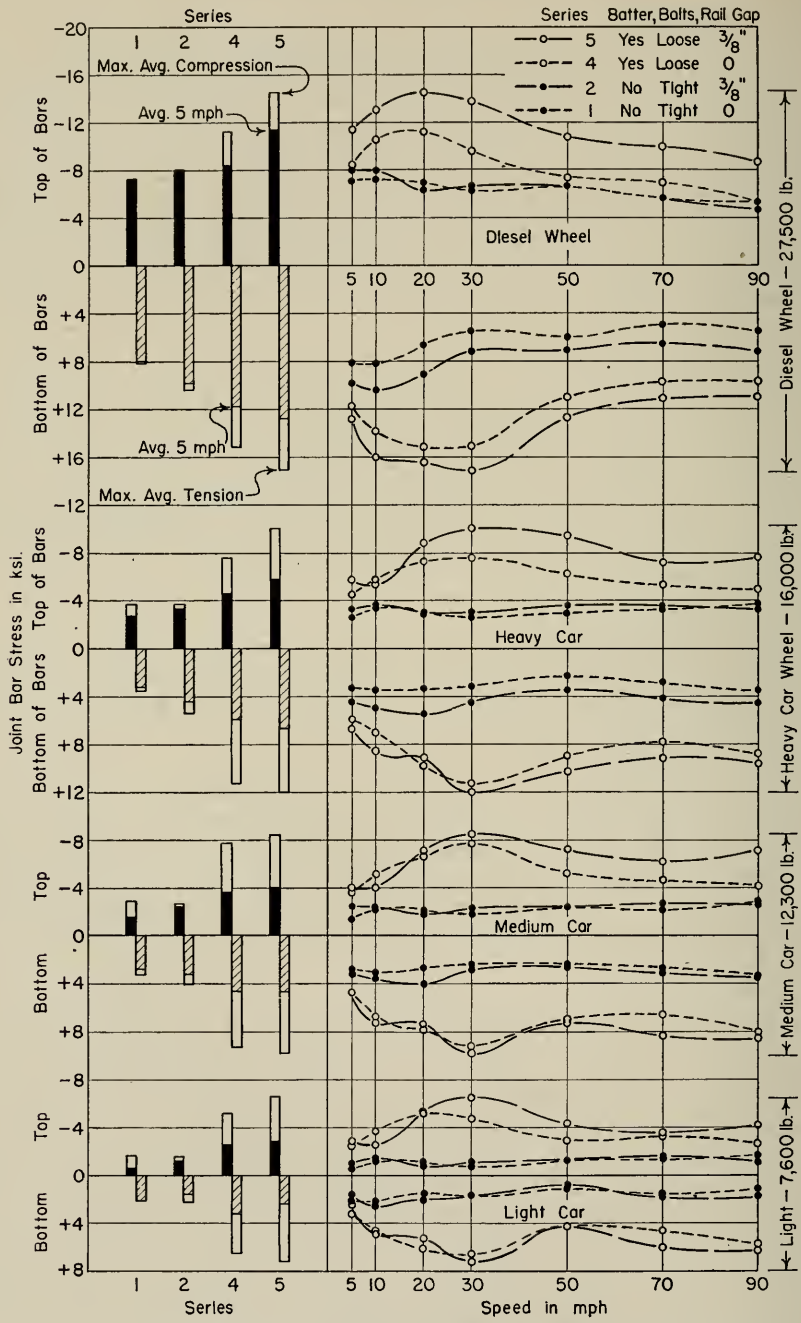


Fig. 6 — Average Stress at Speeds of 5 to 90 mph in Inner and Outer Bars of Joints A and B.

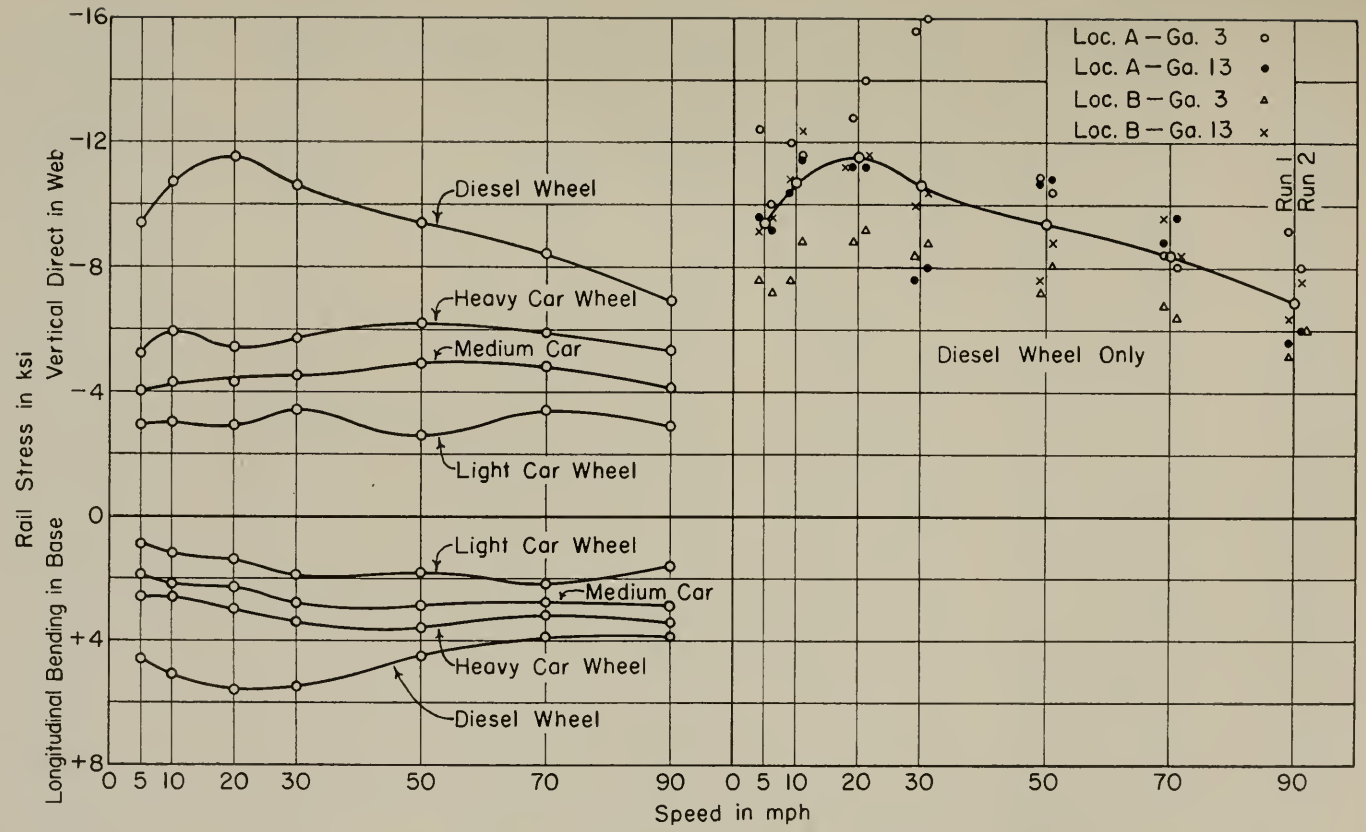


Fig. 7 — Average Stress in Web and Base of Rail I in from Welds A and B at Speeds of 5 to 90 mph — Series 3.

CONCLUSIONS

The following statements seem justified from the data obtained in these tests to determine the impact effect on joint ties due to rail end batter and condition of joint bar support.

Impact Load on Joint Ties

With good joint conditions—little rail end batter and well fitting bars—the added load on the joint ties due to impact effects for the heavy wheel loads is small—less than 1000 lb for a 15,000-lb tie load, or about 5 percent. For lighter wheel loads, the added tie load due to impact is about the same or slightly higher quantitatively, but the total tie load, including impact, is, of course, less. Due to some irregularity in the rail running surface, there is about the same impact load on the ties at the welds as on the joint ties with good joint conditions, for the type of butt welds included in the tests.

With bad joint conditions—0.06-in rail end batter and loosely fitting joint bars—the added tie load on the joint ties for diesel wheel loads is on the order of 7000 lb, with a total tie load of 18,000 lb, or an impact effect of about 60 percent. For lighter wheel loads the added tie load is about the same quantitatively.

The impact effect on the tie load due to the amount of joint gap is negligible for good joint conditions, but is from 1000 to 2000 lb for bad joint conditions.

Accelerations on Joint Ties

For any given rail joint condition the downward acceleration on the receiving joint tie is of about the same magnitude, irrespective of the amount of wheel load. It increases in a straight-line relation with increase in speed. At a speed of 90 mph it reaches a magnitude of about 15 *g* with a good joint condition or a butt weld, and about 40 *g* with a bad joint condition. The frequency of the tie acceleration resulting from the joint impact effect varies with the speed of the train. For 20-mph speed the vertical tie acceleration is at about 100-cycles per second frequency; for the 50-mph speed the frequency is about 200 cycles per second; for 70-mph speed the frequency is from 300 to 400 cycles per second; and for 90-mph speed from 400 to 500 cycles per second. It seems logical to conclude that the high rate of acceleration measured under the bad joint conditions will increase track surfacing costs, tie wear, and tie shattering.

Joint Bar Stresses

Impact effects are practically negligible with good joint condition, but with bad joint condition the joint bar stresses increase approximately 100 percent for the heavy wheel loads. For this latter condition, the joint bar stresses are a maximum at a speed range of about 20 to 30 mph, decreasing at higher speeds. All measured stresses were well within the strength of the bars.

Stresses in Rail Near Weld

The direct stress in the rail web near butt welds, due to the irregularity in the running surface, increases somewhat from 5 to 20-mph speed under heavy wheels, and then decreases in a straight line until the stress is less at 70 and 90-mph speeds than at 5 mph. The bending stress in the base shows a similar pattern. The impact effect for medium and light car wheels in both direct stress and bending stress is small in magnitude, but is greatest at a speed of about 50 mph.

Acknowledgement

The Association is indebted to the Chicago & North Western Railway for its cooperation in the conduct of these tests.

Report on Assignment 11

Rail Damage Resulting from Engine Burns; Prevalence; Means of Prevention; Repair by Welding

J. C. DeJarnette, Jr. (chairman, subcommittee), E. L. Anderson, F. W. Biltz, T. A. Blair, L. S. Crane, C. J. Code, W. J. Cruse, G. H. Echols, P. O. Ferris, J. K. Gloster, J. C. Jacobs, K. K. Kessler, N. W. Kopp, L. R. Lamport, Ray McBrian, B. R. Meyers, W. G. Powrie, C. R. Riley, E. F. Salisbury, W. D. Simpson, A. P. Talbot, R. P. Winton, Edward Wise, Jr.

The committee submits the following preliminary report as information.

This subject had formerly been assigned to the Rail committee under the heading, "Rail Failures Resulting from Engine Wheel Burns, Including Effect of Repairing Such Burns by Oxyacetylene or Electric Welding". A final report on this subject may be found on page 894, Vol. 53 of the AREA Proceedings for 1952. Progress reports on this same subject are in the Proceedings as follows: Vol. 43, page 605; Vol. 44, page 596; Vol. 45, page 445; Vol. 47, page 430; Vol. 48, page 734; Vol. 49, page 429; Vol. 51, page 594; and Vol. 52, page 661.

The committee has canvassed all railroads reporting rail failure statistics as to the extent of their practice of welding engine burns and failures experienced therefrom, and the only railroads reporting this information are included in the tabulation below:

Welded Engine Burns and Failures Reported to December 31, 1954

Railroad	*Total Engine Burns Welded Prior to Dec. 31, 1953*	*No. Engine Burns Welded During 1954*	*No. Welded Elbs Failed During 1954*
AT&SF	250	670	0
B&O	None welded	101	2
CMStP&P	No record	0	0
C&NW	1387*	1984	0
D&H	6950	210	0
D&RGW	None welded	None welded	0
IC	2824*	2530	0
PRR	50134	48313	2
RF&P	3723*	7840	0
SAL	2785*	2161	0
StL-SF	355*	264	0
Southern (West Div.)	99464	23944	1
Southern (System)	No record	No record	4
Totals	167872	88017	9

*No record kept of welded engine burns prior to 1953.

Total number of engine burns welded prior to Dec. 31, 1953—167,872.

Total number of engine burns welded in 1954—88,017.

Total number of welded engine burn failures in 1954—9.

The committee is also accumulating information on means of prevention and methods of repairing engine burns by welding.

PROCEEDINGS

PROGRAM

Fifty-Fifth Annual Meeting

Palmer House, Chicago

Tuesday, March 13, 1956

★

Morning Session—Grand Ballroom—9:30 to 12:00

Address of President G. M. O'Rourke, Assistant Engineer Maintenance of Way, Illinois Central Railroad

Report of the Executive Secretary—Neal D. Howard

Report of the Treasurer—A. B. Hillman

Greetings from the Signal Section, AAR, E. N. Fox (Chairman), Engineer Signals and Communications, Boston & Maine Railroad

Greetings from the Electrical Section, AAR, K. H. Gordon (Chairman), Assistant Electrical Engineer, Pennsylvania Railroad

Address—Fair Treatment for All, by R. G. May, Vice President, Operations and Maintenance Department, AAR, supplemented by new AAR film, "The Right to Compete."

Address—Building People, by H. C. Marmaduke, Consultant, Management-Employee Relations.

Address—Engineering for Mobility, by Lt. Gen. S. D. Sturgis, Chief of Engineers, Department of the Army.

★

Afternoon Session—Grand Ballroom—2:00 to 5:00

Reports of Committees	Bulletin Numbers
20—Contract Forms	525
11—Records and Accounts	527
14—Yards and Terminals	525
Southern Railway Film "Via Sevier."	
Address—Electronic Weighing of Freight Cars in Motion, by V. C. Kennedy, President, Streeter-Amet Company.	
16—Economics of Railway Location and Operation	525
25—Waterways and Harbors	525
Address—Summary of report prepared by AAR Calumet-Sag Committee in opposition to the Calumet-Sag Navigation Project, by A. L. Sams, Office Engineer, Illinois Central Railroad	
9—Highways	525
Address—Transportation, an American Institution, by H. H. Hale, Assistant to Vice President—Highway Transportation, AAR.	

PROGRAM

(Continued)

Wednesday, March 14, 1956

★

Morning Session—Red Lacquer Room—9:00 to 12:00

Reports of Committees — Bulletin Numbers

13—Water, Oil and Sanitation Services ---------- 525

24—Cooperative Relations with Universities ---------- 527

Panel discussion on How Can the Railroads Attract and Hold an Adequate Number of Qualified Engineering Graduates in Competition with Other Industries?

7—Wood Bridges and Trestles ---------- 527

Address—Development of Working Stresses for Glued, Laminated Lumber, by Alan D. Freas, Engineer, Division of Physics and Engineering, Forest Products Laboratory, U. S. Department of Agriculture, U. S. Forest Service.

Address—Application of Working Stresses in Glued, Laminated Lumber, by Frank J. Hanrahan, Executive Vice President, American Institute of Timber Construction, Washington, D. C.

28—Clearances ---------- 526

30—Impact and Bridge Stresses ---------- 526

8—Masonry ---------- 526

15—Iron and Steel Structures ---------- 527

Lantern slide presentation, jointly with Committee 8—showing recent serious damage to railway bridge structures by floods, with commentary by W. R. Wilson, Assistant Engineer, Bridge Department, AT&SF.

★

Association Luncheon—Grand Ballroom—12 Noon

Announcement of results of election of officers

Address by Wayne A. Johnston, President, Illinois Central Railroad, on The Ever-New Challenge of Railway Engineering

★

Afternoon Session—Red Lacquer Room—2:30 to 5:20

Reports of Committees

29—Waterproofing ---------- 526

17—Wood Preservation ---------- 526

PROGRAM

(Continued)

Bulletin Numbers

6—Buildings ---------- 525
Address—Painting of Frame Buildings, by Don F. Laughnan, Technologist, Forest Products Laboratory, U. S. Department of Agriculture, U. S. Forest Service

27—Maintenance of Way Work Equipment ---------- 526

22—Economics of Railway Labor ---------- 526
Address—Better Human Relationships as a Key to Improving Maintenance of Way Work, by W. E. Cornell, Engineer of Track, NYC&STL.

Special Committee on Continuous Welded Rail ---------- 528
Motion Picture "Welded Rail on the Santa Fe," with commentary by R. H. Beeder, Assistant Chief Engineer System, AT&SF.

Thursday, March 15, 1956

★

Morning Session—Grand Ballroom—9:00 to 12:30

Reports of Committees

3—Ties ---------- 526
Panel discussion on Cross Ties.

5—Track ---------- 528
Address—Highlights of Work Performed by Committee 5—Track, by C. J. Geyer, retired Vice President —Construction and Maintenance, C&O.

1—Roadway and Ballast ---------- 528
Address—Landslides and Their Significance to Engineers, by Edwin B. Eckel, Head of the Engineering Geology Branch, U. S. Department of Interior Geological Survey.

4—Rail ---------- 528

Closing Business

Installation of Officers

Adjournment

Report of the Tellers

Presented Wednesday Noon, March 14, 1956

We, the Committee of Tellers, appointed to canvass the ballots for officers and for members of the Nominating Committee, find the count of ballots as follows:

For President

Wm. J. Hedley	1521

**For Vice President*

B. R. Meyers	1505

For Directors (first four men elected)

G. H. Echols	1050
R. R. Manion	853
L. A. Loggins	849
W. G. Powrie	812
W. W. Hay	708
W. T. Rice	638
R. L. Mays	622
F. A. Hess	513

For Members of Nominating Committee (first five men elected)

A. V. Johnston	941
J. C. Jacobs	853
A. B. Stone	842
W. C. Pinschmidt	795
W. M. Jaekle	791
L. V. Johnson	751
F. N. Nye	714
B. H. Crosland	692
J. A. Bunjer	582
P. D. Brentlinger	421

Ten other miscellaneous votes were cast for the various offices listed above.

THE COMMITTEE OF TELLERS,

R. A. BARDWELL, *Chairman*
J. E. WIGGINS, JR., *Vice Chairman*
C. M. BARDWELL
I. C. BROWN
H. B. CHRISTIANSON, SR.
L. S. CRANE
T. F. CREED, JR.
J. C. DEJARNETTE, JR.
J. W. DE VALLE
C. J. GEYER
R. R. GUNDERSON
W. M. HAGER
E. C. HARRIS
F. L. HORN
W. H. KIEHL
H. C. KOELZ
W. F. KOHL
W. E. KROPP
J. R. LATIMER
C. F. LEWIS
J. DE N. MACOMB
RAY MCBRIAN
G. C. MCDONALD
H. L. MCMULLIN
G. A. MCROBERTS
A. W. MUNT
H. C. NORDSTROM
R. S. RADSPINNER
J. W. RISK
G. L. ROBERTS
E. J. ROCKEFELLER
L. E. TALBOT
J. R. TALBOTT, JR.
M. C. TAYLOR
J. N. TODD
A. R. WILSON

Under the provisions of the Constitution, Ray McBrian advances automatically from junior vice president to senior vice president.

PROCEEDINGS

Running Report of the Annual Meeting of the American Railway Engineering Association, March 13–15, 1956, Palmer House, Chicago, Including Abstracts of All Discussion, All Formal Action on Committee Presentations, Specific Papers and Addresses Presented in Connection with Committee Reports, and Other Official Business of the Association

Opening Session—March 13, 1956

President G. M. O'Rourke* Presiding

PRESIDENT O'ROURKE: Ladies and gentlemen: Before I officially call to order the Fifty-fifth Annual Meeting of our Association, I should like to invite your officers, directors, past presidents, and certain special guests to join me at our speakers' tables. I shall be pleased if our two vice presidents and our treasurer will join me at the high-level speakers' table at my right, and if all of our past presidents will join me at the high-level speakers' table at my left. I would ask also that all of our directors come up front and take their places at the second speakers' table directly in front of me. The name plates at the two speakers' tables will indicate the seating arrangement which has been set up for you.

The opening session of the 55th Annual Meeting convened at 9:30 a.m.

PRESIDENT O'ROURKE: The meeting will please come to order. This is the Fifty-fifth Annual Meeting of the American Railway Engineering Association, and the concurrent Annual Meeting of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads.

We have a long and interesting program ahead of us for the next two and one-half days. Indeed, we have already had an interesting start, in the Pre-Convention Motion Picture Theater yesterday, in the Exhibition Hall of this hotel, when 14 railroad films were shown.

The enjoyment of the theater was enhanced, I am sure, by the all-day Coffee Bar provided by our friends of the Simmons–Boardman Publishing Corporation and the National Railway Appliances Association. The interest in these pre-convention features among those who could be in Chicago is indicated by the advance convention registration at the theater of 499 members and 375 guests—a total of 874.

Introduction of Speakers' Tables

Before starting our program for today, I want to present to you those sitting at our two speakers' tables. As I call their names, I shall appreciate their standing and remaining standing until all have been introduced. To save time, please withhold your applause until all have been presented.

I should like to introduce first those who are at the upper speaker's table, and I will begin at my extreme left.

* Assistant Engineer Maintenance of Way, Illinois Central Railroad.

Among the Past Presidents who are with us are:

G. W. Miller, president, AREA, 1954–1955, engineer, maintenance of way of the Canadian Pacific Railway, Toronto.

C. G. Grove, president, AREA, 1953–1954, area engineer, Pennsylvania Railroad, Chicago.

C. J. Geyer, president, AREA, 1952–1953, retired vice president, construction and maintenance, Chesapeake & Ohio Railway, Richmond, Va.

T. A. Blair, president, AREA, 1951–1952, chief engineer, Santa Fe System, Chicago.

C. H. Mottier, president, AREA, 1948–1949, vice president and chief engineer, Illinois Central Railroad, Chicago.

Armstrong Chinn, president, AREA, 1947–1948, and president of the Terminal Railroad Association of St. Louis, could not be with us yesterday, but did expect to be in this morning. We are still looking for him, and expect him to put in an appearance at any moment.

And, finally, A. R. Wilson, president, AREA, 1936–1937, retired engineer of bridges and buildings, Pennsylvania Railroad, Lansdowne, Pa.

On my extreme right, Ray McBrian, junior vice president, AREA, engineer of standards and research, Denver & Rio Grande Western Railway, Denver, Colo., and Wm. J. Hedley, senior vice president, AREA, assistant chief engineer, Wabash Railroad, St. Louis, Mo.

The next two gentlemen I shall skip for the time being.

Then, A. B. Hillman, treasurer, AREA, and chief engineer of the Belt Railway of Chicago, and the Chicago & Western Indiana Railroad, Chicago.

And finally, Neal Howard, executive secretary of the AREA.

Now, gentlemen, you may give these gentlemen a nice hand. [Applause]

At my extreme left at the lower table (if you will greet them in the same manner that you did these gentlemen at the other table), I would like to present E. S. Birkenwald, director, AREA, engineer of bridges, Western Lines, Southern Railway System, Cincinnati, Ohio.

H. B. Christianson, Sr., director, AREA, special engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago.

B. R. Meyers, director, AREA, chief engineer, Chicago & North Western Railway System, Chicago.

C. B. Porter, director, AREA, assistant to the vice president, construction and maintenance, Chesapeake & Ohio Railway, Huntington, W. Va.

C. H. Sandberg, director, AREA, assistant bridge engineer, system, Atchison, Topeka & Santa Fe Railway, Chicago.

W. H. Giles, director, AREA, assistant chief engineer, Missouri Pacific Railroad, St. Louis, Mo.

H. R. Peterson, director, AREA, chief engineer, Northern Pacific Railway, St. Paul, Minn.

E. J. Brown, director, AREA, chief engineer, Burlington Lines, Chicago.

F. R. Woolford, director, AREA, chief engineer, Western Pacific Railroad, San Francisco, Calif.

And R. H. Beeder, director, AREA, assistant chief engineer, Santa Fe System, Chicago.

Now, you may show those gentlemen how glad we are that they are with us. [Applause]

We regret that, due to illness, two of our directors cannot be with us this year—G. E. Robinson, engineer of structures, Lines West, New York Central System, Chicago; and C. J. Code, assistant chief engineer—tests, Pennsylvania Railroad, Philadelphia, Pa. We regret very deeply that they could not be with us.

In making the introductions so far, I purposely skipped over the two special guests at our speaker's table. I should like to introduce them to you now. I refer to two of the gentlemen on my right, who are official representatives of our sister sections in the Engineering Division of the Association of American Railroads.

I should like to present first, Mr. A. L. Essman, chief signal engineer, system, Burlington Lines, who is first vice chairman of the Signal Section, Engineering Division. Mr. Essman is sitting in for the chairman of the Signal Section, Mr. E. N. Fox, engineer of signals and telegraph of the Boston & Maine Railroad, who could not be with us this morning because of illness. I should be glad if Mr. Essman would rise and be recognized. [Applause]

I should now like to introduce the second of these gentlemen, Mr. K. H. Gordon, assistant electric engineer, Pennsylvania Railroad, who is chairman of the Electrical Section of the Engineering and Mechanical Divisions, AAR. [Applause]

I shall recognize both of these gentlemen further, a little later in our program.

And now I would like to recognize and welcome the ladies in the balcony who have come in to join with us in our opening session. [Applause] We are delighted and honored to have them here, and hope that they will feel at liberty to drop in on any of our other sessions, because feel it is important that they know something about the work of this great Association to which their husbands give so much of their time and talent.

I would particularly invite you ladies to our closing business session on Thursday, beginning about noon, when our new officers for the coming year will be installed.

I want you to know too, that you are welcome—indeed, urged—to participate in all of the women's activities during the convention. Information concerning these functions can be secured in the Women's Reception and Registration Room on the third floor.

The first official order of business of our annual meeting is consideration of the minutes of our last annual meeting. These minutes were printed in Vol. 56 of the AREA Proceedings for 1955, a copy of which was furnished to each member. Unless I hear some correction or objection, we will dispense with the reading of these minutes.

Hearing no corrections or objections, I declare the minutes approved as printed in the Proceedings.

Address of President George M. O'Rourke

It is rather awe-inspiring to me to see so many of you here this early in the morning. It has been a long time since this room has been so nearly filled at an opening session as it is at this time.

The Constitution of our Association requires the President to deliver an address at the annual convention. It is a distinct privilege, but the realization that it had to be done haunted me throughout the year.

At the beginning, I imposed upon myself the preparation of a message to be printed each month in the AREA News. The result was that, when the time came for composing the President's Address, instead of having a lot of subjects promising great possibilities stored away for use in writing the swan song of my official life, I was like Mother Hubbard who found her cupboard bare.

The Association, in definitely prescribing this order of business, must have been willing to assume great risks and prepared to absorb a large amount of punishment. When a speaker is given such freedom in the choice of his subject matter as is granted the President, simply the obligation of making an address, he, knowing that it will be placed in the archives for our descendants, may prepare a most learned document, the result of months of research, designed more for the enlightenment of posterity than for the interest of his listeners.

You are not interested in any extended historical recital of what has been done or to glory in it, but like a certain well known commentator of a few years ago, you are primarily concerned with "predictions of things to come" to see more clearly the tasks that lie ahead and to learn how we can do them better. Therefore, I shall be brief with my account of the activities of our Association during the past year.

Financially, the Association has had a very good year. Later I shall call upon Treasurer Hillman and Executive Secretary Howard to present the statistics. These two men, with Edward Gehrke, assistant secretary and his staff, have formed a bulwark of strength to your president. It has been a real pleasure to have been associated in this work with Neal Howard. The Association does not realize the fund of knowledge and excellence of judgement with which he is always ready to help the current administration. The burden of the details of the year's work falls on the executive secretary's office. It is here that your reports pass through the processes of editing, proofreading and final checking. My observation is that his office is working under peak load. If we have accomplished things that are worth while, it is due to your efficient executive secretary, his sole thought being to promote your best interests and to make the current administration of greater value to you than any preceding one.

The American Railway Engineering Association functions as the Construction and Maintenance Section of the Engineering Division of the Association of American Railroads and, by virtue of his office, the president of the American Railway Engineering Association is chairman of the Engineering Division of the Association of American Railroads. I record here our thanks and appreciation for the cooperation and support of the vice president, Mr. May, who has graciously agreed to address our convention later on in the program.

The past presidents, the vice presidents and the Board of Directors have shown throughout the year's work an unfailing zeal and spirit of willing cooperation, for which I wish to express to them my most heartfelt appreciation and grateful thanks.

I speak for the officers and the Board of Directors and state that we are sensible of the hearty support accorded by the chairmen of the several committees, and for that I make due acknowledgement. It has long been recognized that the value of the Association is founded largely, if not entirely, on the strength and industry of its committees. The work they carry on is brought to a conclusion each year when they present their reports at the annual convention. As the Bulletins show, the committees have again done a large amount of work and substantially advanced their studies on the subjects assigned to them.

Time does not permit a review of current work of all committees, but some activities of rather special character should be mentioned. A committee known as the Committee on Arrangements, always untiring in its zeal to see that our program has been well prepared, and that we will have an enjoyable time, it due a full measure of appreciation.

Few of our members realize the fine work that has been done in recent years by our Research Committee, working with Mr. Magee, director of engineering research, Asso-

ciation of American Railroads. Mr. Magee currently has under way 39 engineering research projects covering practically every item used in the construction and maintenance of track and structures.

The engineering research laboratories of the Association of American Railroads are on the campus of Illinois Institute of Technology here at Chicago. You should visit them. They have steadily grown in size and scope. Work soon will begin on a new engineering laboratory, estimated to cost $470,000. Engineering research this year will require $365,000. These are matters handled by the Research Committee collaborating with Mr. Magee and Mr. May. I think you may hear more on the subject from these gentlemen later.

I am sure that the whole membership would wish me to express appreciation to the National Railway Appliances Association for its continued interest and cooperation in making our convention a success. We are particularly grateful for the wonderful showing of machinery, equipment and supplies in exhibit years and for the things it can do, within its Constitution, in off-exhibit years. Those of you who were fortunate enough to be here yesterday to attend the Monday movie must have enjoyed the coffee bar sponsored by the National Railway Appliances Association and the Simmons-Boardman Publishing Corporation. It is open each morning just off the foyer, and you will find a genuine welcome there.

Railway Track and Structures, Railway Age and Modern Railroads will provide issues of their magazines, available in the foyer, thus helping to keep up our interest and inform us of current events during the convention. They too are entitled to the gratitude and thanks of the members.

We will miss some familiar faces at this convention, men who have aided us in placing our Association on its high plane of usefulness. It will be Mr. Howard's sad task to announce that we have lost several of our members by death during the past year. May their souls and all the souls of the faithful departed, through the Mercy of God, rest in peace.

A thrilling and impressive experience came to your president almost 50 years ago, a couple of years after being employed by the Illinois Central Railroad. I was chosen to work for Louis Charlton Fritch in the first studies made for the proposed lake front passenger terminal. For almost a year I was with him and had the highest regard for him. After joining the American Railway Engineering Association, I enjoyed the pleasure of visiting with him frequently at Association affairs. Need I remind you that he was a charter member of the Association, honorary member, first secretary and eighth president? He died on July 23, 1955. Eternal rest grant unto him, Oh Lord, and let perpetual light shine upon him.

Last Christmas President Eisenhower presented Mrs. Eisenhower a medal for her unfailing cheerfulness in following him all over the world and establishing a home wherever he might be.

There is a group of marvelous, wonderful women up there in the balcony, each one of whom deserves a medal—our wives and daughters—who followed us from pillar to post up and down the railroad, establishing a real home for you and me, often in houses where home-making was most difficult; sending us away each morning with a prayer and a word of cheer and meeting us in the evening with sympathetic love and affection.

I should be remiss indeed if I did not especially mention Whitney Howard who has guided the women through annual conventions for several years. She is kind and patient and deserves an extra star on her medal.

I am reminded of an ancient church in Aachen, Germany, where there is a lone pew on a balcony where Charlemagne knelt "between my God and my people." As you good women look down upon "your people" give us the benefit of your benign blessing for a good convention. Ladies, we salute you from the bottom of our hearts.

Your attention is drawn to the publications of the Association during the past year. In addition to the Bulletins which have been issued covering the committee reports to be made to the convention, there have been other and miscellaneous publications, such as the brochure entitled "The Railroad Field—A challenge and Opportunity", prepared by Committee 24—Cooperative Relations with Universities. This brochure is, without doubt, one of the most forward-looking steps ever taken by the Association. The president's message in the September 1955 issue of the AREA News describes it in considerable detail. I quote the last paragraph:

"As we are saying to the heads of the different engineering schools in transmitting copies of the brochure to them, we sincerely hope that the copies sent will assist many of their students in choosing careers wisely, and on the other hand, will be helpful to the railroads in enabling them to attract into their employ each year the number of qualified graduates necessary to maintain and improve their high standard of service to the country in the years ahead."

Let us substitute the words "American Railway Engineering Association" for the word "country" in the last line. Every young engineer realizes soon after being employed by a railroad that he has just begun to accumulate the knowledge which he will need before he attains a position of responsibility. He finds himself dealing with more or less routine, or mechanical matters; but as he acquires knowledge, experience and maturity, he is assigned problems involving professional knowledge and judgment. How is he to acquire such knowledge and judgement quicker than by the long years and hard knocks of experience?

His employer should advise him that a college education, however acquired, seldom hurts a man if he's willing to learn a little something after he graduates, and then direct him to join the American Railway Engineering Association. There is no greater post-graduate school nor opportunity for the attainment of knowledge in the science of transportation than through work in the American Railway Engineering Association; and for the young man unable to get a college education, this is not a convention chamber, these are truly "The Halls of Ivy" for him.

The Association is a great continuation school coming after the university, if you please, and an education to those in the mood to receive it. If a young engineer is not interested, he is out of luck and had better make a change and get into something in which he can be interested.

The American Railway Engineering Association is engaged in the higher practical education and training of its young members not only to an understanding of the economies of construction, maintenance and operation of railroads, but also in the qualities that make for leadership, a friendly interest in and understanding of his fellowmen—all growing out of a better acquaintance with them. It has an educational value from the personal contact in the intensive committee service from the exchange of ideas, and the spirit of compromise.

Thus the railroads will benefit. As for the American Railway Engineering Association I feel that in order to assure the continued healthy growth of our organization it is necessary that a substantial portion of the new membership shall consist of young personnel. This was the theme of my first message from the president in the April 1955

issue of AREA News and again in the December 1955 issue. If you did not read them I hope you will.

When I entered the engineering department of the Illinois Central Railroad 51 years ago, America was emerging from the gay 'nineties and plunging into the ensuing railroad panic of 1907. Immigration was still at high tide. Railroad maintenance-of-way labor was plentiful and practically unorganized. Comparatively small though they were, our paychecks were all our own. "Deducts" didn't get any of it then.

The first movie parlor that grew into today's cinema palace began that year, 1905, on the east side of State St. between Monroe and Adams toward the south end of what is now the Palmer House, where we are assembled. Little did I realize when I attended that opening that some day, as president of the American Railway Engineering Association, I would be conducting a moving picture show for the enjoyment of the members who arrive on Sunday and Monday for our convention. The attendance at the show yesterday was approximately 860, and we are told that everyone who saw it thought it was very much worth while.

The American Railway Engineering Association then was to the young man an order of eminent mystics who met primarily to compare notes on great achievements. Thirty-seven years ago I was honored with membership in the American Railway Engineering Association. I recall a large number of operating department officers, division superintendents, general managers, and vice presidents who were members. A far greater proportion of our members moved over into the operation or transportation departments on many more railroads then is the case today. Why? Is it because the work of Committee 16—Economics of Railway Location and Operation, is not known to our transportation department officers? How many in our own Association know very much about the work of Committee 16? Should our trade publications bring to the attention of operating men the work of our Association in railroad operation studies and suggest that more of those railroad men again join our Association? The most perilous disease in the world is not leprosy, but lopsidedness. Are we becoming lopsided? In the eyes of some operating department officers, I fear, we are convicted of plain bankruptcy in railroad operation intelligence.

During the past several years we have not had as many monographs on interesting and important subjects as we did when I was a young man—valuable monographs contributed by members. They were timely. Many were on railroad operating problems as well as on engineering subjects. I especially urge that the members make it a point to give the Association the benefit of specially prepared papers on subjcts of vital interest to our Association.

I shall not attempt to talk about the Weeks report, wage increases on our railroads, payroll taxes, fringe benefits, unemployment and sickness benefits, diesel locomotives, high-speed, lightweight passenger trains and notable engineering projects and research. There are men in this audience eminently better qualified to speak on these subjects than I am. It would, therefore, be a sterile presumption on my part to try to discuss them. So now, let us proceed with the work for which we have assembled.

Today is the 13th of March. This convention ought to be an auspicious one, for was not "13" the number of the original states of our glorious Republic and "13" the number of letters in the motto of our State Coat of Arms, E Pluribus Unum, while in one claw, the eagle holds 13 sharp pointed arrows, and in the other an olive branch with 13 leaves? Moreover, the words "City of Chicago", my home town, which lends it hospitality for our convention, contains 13 letters. Let us proceed with confidence and with enthusiasm.

We come now to a brief reference to the future. The Association is facing a different world from that of the founding fathers. The great problems of the railroads today are in economics and in public and human relations, and the Association should take its proper place in these considerations. The railroad maintenance engineer of tomorrow faces a radically changed set of conditions in a drastically altered atmosphere. Some of our special features and addresses will be about people, employer–employee relationship, safety, etc., as well as the economics of railway labor. It is evident to all that we are on the threshold of great developments. The days and years to come will be challenging; they will call for the best we have to give.

And now, my friends, I thank you for having listened to me, and we will proceed with the regular program.

PRESIDENT O'ROURKE: The next order of business is the report of our secretary, recently given the title of executive secretary, as the result of a change in the Constitution voted by the membership. Mr. Howard, will you please present the report of the executive secretary?

Executive Secretary's Comment

Mr. President, past and present officers of the Association, members and guests:

First, since President O'Rourke has mentioned my new title, may I thank the Board of Direction for proposing it and the membership for approving it. I did not ask for this more impressive title, nor did I promote it, but the very fact that it is more impressive than the former title of secretary does, I am sure, add prestige to the office and to the Association in dealings with those who are impressed by such things.

I cannot overlook, too, the very generous compliments of your president to the secretary and his staff, which are greatly appreciated. Gentlemen, I am not sure they are merited, but of one thing I am sure, and that is that, as he has said, our constant interests and endeavors are in your behalf.

With time of the essence in our full morning program, which will crowd the noon time recess hour even if I were to take none of your time at all, I will with your permission, be very brief, especially since the secretary's report is published in full in the March Year Book Bulletin, copies of which were mailed early in March, and which will be on your desks upon your return home, if they have not already been received.

But I do want to assure you, pending your own review of the report, that the Association has had another successful year, thanks to the interest and efforts of your officers and directors, your committee chairmen and some 1100 other committee members, and to the effective cooperative arrangement which our Association has with the Association of American Railroads. Again, while adhering to its objective, much has been accomplished for our members and for the railroad industry through committee efforts and associated research work; membership interest has remained at a high level; the membership rolls during the year rose to an all-time high of 3303 as of February 1, 1956, despite heavy losses due to death and other causes—continuing further the unbroken record of membership increase each year since 1944; and by no means unimportant, the Association continued in a healthy financial condition, as will be disclosed to you by our treasurer, I am sure.

In the interest of brevity, I would like to stop here on this pleasant note, but I would be less candid if I did not point out, for one thing, that, large as our mem-

bership is, it does not include the names of many qualified engineering and maintenance men of the railroads who would benefit from membership and who would contribute to the welfare of the Association and the railroads through membership. Also, that our roster of Junior Members is far from what it should be in the interest of the growth of these young technical graduates on the railroads, and the further welfare of the railroads themselves.

Maybe we have other weaknesses or shortcomings, in spite of our constant self appraisal and efforts. With that possibility in mind, we have welcome as a part of the organization and management study of the AAR (of which we are a part) the searching analysis that has been made in recent weeks of every phase of the organizational structure and operation of the AREA, both through detailed inquiry within the secretary's office and among officers and members generally on a considerable number of railroads.

This study has not been completed as yet, and there is no indication of what its findings may ultimately be regarding our Association, but of this you may be certain—it was with pride on your behalf that your secretary's office unhesitatingly unfolded the records of your operations and achievements over the years.

In closing, may I just say on behalf of the secretary's office—it has been wonderful working *with you and for you* another year. We appreciate all of your help and consideration, and appreciation, and we stand ready, insofar as we possibly can, to help you make 1956 a still better year for the Association.

President O'Rourke: Thank you, Mr. Howard. I am sure that the membership was pleased to learn that the Association has had another good year in every respect, although I share with you, as does the Board, I'm sure, concern over several matters, particularly the further reduction in the number of our Junior Members, which could have ominous forebodings, not alone to the Association but for the railroads as well, unless corrected.

I am sure that many of you will want to read carefully the entire report of the executive secretary as published in the March Bulletin, which was mailed about March 1, and which will be in your hands upon your return home, if it has not already been received.

We will now hear the report of our Treasurer, A. B. Hillman, chief engineer of the Chicago & Western Indiana and Belt Railway of Chicago. Mr. Hillman.

Treasurer's Report

Mr. President, members, guests:

Last year's Treasurer's report stated that financially the Association would end the year 1955 with a substantial deficit. I am happy to report that my financial forecast was in error. Total receipts for the year were $6254.03 in excess of total disbursements.

Receipts for 1955 were some $5570 under those of 1954, which decrease was more than accounted for by the more normal Manual receipts of $6770 in 1955, which were some $11,000 under Manual receipts in 1954. The large Manual receipts in 1954 accrued from the heavy demand for the newly printed Manual, available for sale in November 1953.

Offsetting this decrease in Receipts was an increase of some $4500 in Track Plan receipts due entirely to the sales of the 1955 Supplement to the Portfolio of Trackwork Plans. Other Receipts items for 1955 were in very close proximity to those of 1954.

Disbursements for the years 1954 and 1955 are not comparative for several reasons, primarily, expenditures for Track Plans, Engineer Recruitment Brochure, and Manual. Total Disbursements in 1955 were $5880 higher than in 1954. In 1955, $3391 was expended for the Brochure, with no expenditure for this item in 1954, and Track Plan expenditures in 1955 were $7333 greater than in 1954–1955 disbursements being $10,724 higher for those two items over 1954 disbursements.

Conversely, Manual expenditures were $3514 lower in 1955. Also, due to favorable conditions and printshop economies, expenditures for the items of Proceedings and Miscellaneous Stationery and Printing were $2100 under like expenditures in 1954.

Therefore, higher expenditures for Track Plans, Brochure, and Annual Meeting of $11,124, 1955 over 1954, and lower expenditures for Manual, Proceedings, Miscellaneous Stationery and Printing of $5614, leaves a differential of $5510. This differential, compared to total higher expenditures of $5880 in 1955 over 1954, indicate that even with a slight increase in the cost of doing business in 1955, expenditures for all other Disbursements items approximated those of 1954.

Association finances for 1956, with no major revisions to existing publications, or comprehensive new publications contemplated for 1956 at the present time, should revert to a normal year, in which Receipts will exceed Expenditures by a small amount.

PRESIDENT O'ROURKE: Thank you, Mr. Hillman.

You know, I can't help but express once again the pleasure of the officers here, and myself, over the number of people in this audience this morning. It is certainly very heartening to see the room almost completely filled. There are some empty chairs up in front for you men who are standing along the sides. If you will come up here and sit down, you'll make us all more comfortable and happy.

Again, Mr. Hillman, I'd like to say that it is a great source of satisfaction to all of us, I'm sure, to have your assurance that our Association is in good financial condition, in spite of the several unusually large expenditures during the year to further the work of the Association and the interests of the railroads.

You have heard the reports of the executive secretary and the treasurer. What is your pleasure? I shall be glad to entertain a motion that they be accepted.

[Motion was regularly made and seconded that the reports of the executive secretary and the treasurer be accepted; the motion was put to a vote, and carried.]

Greetings From the Signal and Electrical Sections, AAR

PRESIDENT O'ROURKE: Meeting here today not only as the American Railway Engineering Association, but also as the Construction and Maintenance Section of the Engineering Division, Association of American Railroads, it is highly appropriate that we should have invited to be with us again on this occasion, official representatives of the other two sections of the Engineering Division, namely, the Signal Section and the Electrical Section. Our relationship with these two sections has been a pleasant and profitable one over many years, and I am sure that it will continue as such long into the future.

The official representatives here of these two sections have already been introduced to you, but I should now like to recognize them further by calling upon them for a few words of greeting, should they desire.

The first vice chairman of the Signal Section is Mr. A. L. Essman, chief signal engineer, system, Burlington Lines. Mr. Essman, will you come to the microphone?

A. L. Essman: Mr. President, Officers, Members and Guests of the American Engineering Association: I feel privileged to be asked to extend greetings from the Signal Section of the Association of American Railroads, but regret that our chairman, Mr. E. N. Fox, engineer of signals and communications of the Boston & Maine Railroad, was unable to have this honor because of having undergone an operation. But I am happy to state that he is recuperating nicely.

We of the Signal Section feel sort of bound to the AREA because of our allied interests. For example, take track, ballast, bridges, etc., which are so ably dealt with by your Association. Of most importance to us is the track upon which we superimpose our track circuit, which serves as the basis of operation for practically all signal systems. As result of this, we are keenly interested in the type of rail, because of our bonding; the type of switches, because of the necessity to detect, in the case of hand-operated switches, that they are in full normal position. In the case of interlocked switches, our interest there lies in practically every part of the switch.

In connection with movable bridges, our interests are with the alinement and the interlocking of same. Problems that occur in any of the materials or equipment with which you work, and in which we are allied should be considered as mutual problems, and the Signal Section is ready to cooperate and work with you toward a solution.

Our allied interests are many and I am reminded of an incident which occurred a few years ago when your executive secretary, Mr. Howard, called upon the Burlington to present a three-way symposium on "Cooperation Between the Track, Bridge and Signal Departments" at the Maintenance of Way Club of Chicago. One of your directors, E. J. Brown, and incidentally, my boss, Mr. Emmet Sheehan, then Supervisor of Bridges, and myself, participated in this symposium. After the three of us concluded our remarks, the former chief engineer of the Chicago & North Western, Mr. E. C. Vandenburgh, took the floor and stated that our symposium sounded more like a testimonial dinner in that we seemed to brag about how well we cooperated with one another. I agree with him, it may have, but the thought that I hope to leave with you gentlemen here is that it is the desire of the Signal Section of the Association of American Railroads, in working with your group, that when the job is done, it may appear also as a testimonial. Thank you. [Applause]

President O'Rourke: Thank you, Mr. Essman. It is good to have you here this morning.

We should now be pleased to have a word from Mr. Gordon, chairman of the Electrical Section, who is assistant electrical engineer of the Pennsylvania Railroad.

K. H. Gordon: Mr. President, Members of the American Railway Engineering Association, and Guests:

A man boarded a ship at New York, bound for Europe, and the first day out a group of men invited him to join a game of cards. "Oh, no," he said, "I'm strictly an amateur at cards. In fact, I haven't had a deck of cards in my hand for years, and my playing would just bore you." They insisted that they were amateurs also and that the stakes were not high, but he stood by his refusal. However, as unobtrusively as possible, he watched the game for an hour or so and concluded that the players were anything but amateurs and the stakes were substantial. The next day they approached him again and after some demurring he permitted himself to be persuaded to play. He picked up the deck of cards, shuffled it once in expert fashion, looked around the table at the other players and asked—"How come the ace of spades is missing from this deck?"

Gentlemen, it is indeed a pleasure to stand before you this morning and bring you the greetings of the Electrical Section, Engineering and Mechanical Divisions. We are

probably not as much an expert in our calling as was the self-styled amateur of the story in his. In fact, we find that we must be somewhat of a jack-of-all-trades. We even get into a problem now and then relating to coal traffic. One of our committee reports for this year will contain the following statement: "If electric generation by atomic power should develop at the predicted maximum rate to 1980 and total electric generation should reach only the predicted minimum, the coal industry would have to supply more than 60 percent more coal annually to the power industry than it is doing today. On the other hand, if electric generation by atomic power should develop at the predicted minimum rate to 1980 and total electric generation should reach the predicted maximum, the coal industry would have to supply between four and five times the present amount."

The weekly energy generated by power companies and publicly owned plants topped 11½ billion kw-hr this winter, as compared with 7 billion kw-hr five years before. A large part of this energy was generated by the burning of coal hauled by the railroads. I need not tell you how important electricity has become in the operation of our railroads, or of how that importance is growing. You are in a position to see it every day on your own properties—in your communications, signal plants, shops, and other facilities, to say nothing of your diesel-electric locomotives. An interesting statistic, however, is that the electrical generating capacity installed in diesel-electric locomotives on Class I railroads is now greater than the installed hydro-electric generating capacity in the country, both privately and publicly owned, which amounts to about 22 million kilowatts, or nearly 27 million horsepower.

In closing, I wish to assure you that the Electrical Section stands ready to collaborate with you and to assist you in any of your projects in which our help may be of value. [Applause]

President O'Rourke: Thank you, Mr. Gordon. We appreciate your being with us this morning, and would be pleased to have both you and Mr. Essman remain with us to participate in features of our annual meeting, to the extent that you are interested and that your time will permit.

Aware that there are in our audience a considerable number of members of both the Signal and Electrical Sections, as well as members of the Mechanical, Purchases and Stores, and other divisions of the AAR, and also representatives of other groups in which our Association is interested, I want to tell each of you how happy we are to have you with us, and to extend to each of you a cordial invitation to participate in all of those sessions of our annual meeting in which you may be particularly interested.

Since the American Railway Engineering Association functions also as the Construction and Maintenance Section of the Engineering Division, AAR, within the Operations and Maintenance Department of that Association, we are highly pleased to have with us again this year, Mr. R. G. May, vice president of the Operations and Maintenance Department, AAR, who, we are sure, will bring us a timely message.

As you know, Mr. May is an engineer by training and experience, who came to the Association in 1953 from the New York Central System, where at the time he was vice president in charge of operations and maintenance. We are honored and pleased to have him with us again this morning, to address us on a matter which is of vital interest to the railroads and to each one of us.

Fair Treatment for All

By Richard G. May
Vice President, Operations and Maintenance Department,
Association of American Railroads

I assure you it was a pleasure to receive an invitation to address you today. I know of no group in the railroad industry which works any harder than the members of AREA. Too, I might add, were it not for the efforts that you put forth in these times of intense competition, the railroads would not be nearly so well prepared to stand up and compete with our subsidized competitors.

To meet the odds stacked against them by inequalities in the transportation field, the railroads have had to rely heavily on you to devise methods which will reduce maintenance and construction costs and provide safer, more economical transportation.

Technological accomplishments have enabled the railroads to streamline their plant and accelerate schedules. Of equal importance, achievements in engineering have helped the railroads to effect economies that make it possible for them to continue to maintain low rates for both shippers and travelers in an extended era of spiraling prices.

But no matter how hard you strive to conceive the most modern methods, no matter how much success you attain in keeping costs at the lowest level, the railroads still have their severest obstacle to overcome in the regulations and policies under which they are presently forced to compete for traffic.

And that brings me to the heart of my subject—namely, "Fair Treatment for All."

If any industry is shackled by inequitable regulations, it is today's railroads. You have only to review the findings of the Presidential Advisory Committee on Transport Policy and Organization to detect these disparities.

As most of you know, the Cabinet Committee dealt with various aspects of transportation in its report. But its key recommendation is that in the current competitive transportation field, greater reliance should be placed on competition in pricing among the various types of carriers.

Briefly stated, the Cabinet Committee considers the right of shippers to select their mode of transportation, on a competitive basis, as the "cornerstone" of a modern system of regulation designed to bring about more effective use of the nation's transportation resources.

In contrast, as matters now stand, one of the major yardsticks applied by the Interstate Commerce Commission in its control over rate competition among the different modes of for-hire transport is the concept that the government's power to regulate rates should be used to see that each form of carrier gets what the ICC deems to be its "fair share" of the available traffic.

Such a policy of attempting to allocate traffic among the various types of carriers requires, in effect, that one form of transportation hold an "umbrella" over the rates and traffic of its competitors.

But the Cabinet Committee feels—just as we do—that where one form of transportation, by its inherent nature, is capable of moving a given commodity between certain points at a lower rate than competing carriers, at a profit and without discriminating against other shippers—it should be allowed to handle the traffic.

In essence, the Cabinet Committee is convinced that the law should make it clear that, through its power of rate regulation, neither the ICC nor any other governmental body should undertake to allocate and divide business among the different forms of transport.

Now, in taking this position, the Cabinet Committee did not recommend stripping the ICC of its power to regulate rates. Rates would continue to have to be published in tariffs filed by the carriers with the ICC, and still would have to be adhered to as published.

Moreover, rates still would not go into effect ordinarily until 30 days after filing, and there still would be opportunity for shippers or other carriers to protest, or for the ICC to act on its own motion.

Furthermore, the ICC would still have responsibility and power to see that rates are neither unreasonably high nor unreasonably low—the principal test being that they shall be compensatory to the carrier proposing them—and that they do not unjustly favor, or discriminate against, any person, any community, or any region.

But within these limitations, the recommendations of the Cabinet Committee contemplate that competitive pricing, as well as competition in service, should prevail.

Such a result, I might add, could be achieved by a simple change in the statutory standards to be applied in determining whether a proposed rate is lower than a reasonable minimum, without affecting the other standards applied by the ICC.

The essential standards would continue as they now are, except that in determining whether a proposed rate would be less than a reasonable minimum, the ICC should not consider its effect upon the traffic of any other mode of transportation, nor its relation to the charges of any other mode, nor whether it is necessary to meet the competition of any other mode of transportation.

Under such a proviso, there would be a natural rather than an artificial division of traffic among the competing forms of transportation. In this manner, each type of carrier would receive that share of available traffic it is qualified to handle most efficiently and economically in the eyes of shippers and the public.

Despite the forthright wording to the Cabinet Committee report, there are repeated assertions by truck and barge spokesmen that this recommendation for greater freedom of competition between different types of carriers would revert transportation to the state of "cut-throat" tactics said to have existed prior to passage of the original Act to Regulate Commerce in 1887.

Here I would like to emphasize that there is not a chance of a return to the conditions of 1887—either in the physical facts of transportation or the legal terms under which our business is conducted.

With competition as keen as it is and the laws already as clearly defined as they are—and as they will remain if greater freedom in competitive pricing between the different modes of carriage is adopted—it is sheer nonsense to believe that a transportation monopoly could be either created or sustained.

Neither does the argument of critics that permitting greater freedom in the making of competitive rates would enable the railroads to destroy motor and barge carriers "hold water," because, under both the Cabinet Committee's recommendations and present law, railroads could not make below-cost rates.

Nor is there any validity in the assertion of opponents of the Cabinet Committee's recommendation that greater freedom in competitive rate-making would burden shippers of so-called non-competitive, or "rail-bound" traffic.

On the other hand, what the shippers of non-competitive traffic have real reason to fear is that competitive traffic will continue to be drained from the railroads, thus increasing the burden of overhead and fixed expense which will have to be borne by the traffic remaining on the rails.

May I remind you, in closing, that it is not that we in the railroad industry object, particularly, to the truckers and inland waterway operators opposing the recommendations of the Cabinet Committee. Everyone is entitled to his own opinion. But what we do object to is the manner in which they are attacking the conscientious work performed by a group of patriotic government officials on behalf of the transportation industry.

And that is where you gentlemen fit into the picture. If the American people are to be accurately acquainted with the valuable work of the Presidential Committee, on an unbiased basis, it is up to you and me—at every opportunity—to give the unvarnished facts; in short, to keep the record straight.

To help us do this—to assist us in lifting the "smoke screen" our friends on the other side of the competitive fence have thrown up for the purpose of dividing public opinion—the railroad industry has produced a new 14-minute technicolor motion picture on the subject.

We are proud at this time to present on film the railroad's version of "The Right to Compete."

[The motion picture was then shown.]

PRESIDENT O'ROURKE: Thank you, Mr. May. You have brought us a timely message of vital importance to the railroad industry, our Association, and to each of us individually. I am sure that the railroad industry can count upon this Association and its members individually to foster and promote the proposed federal legislation to implement the recommendations contained in the Cabinet Committee Report. As you say, all we are asking is fair treatment for all, and conditions of fair competition. Thank you again for being with us again this year.

Introduction of Foreign Railroad Men

PRESIDENT O'ROURKE: I would like to interrupt the proceedings at this point for just a moment to perform a pleasant task. As in the past, we have with us today some foreign railroad men. These include four men from Thailand, a country that at present —and we know that it will remain so in the future, from its history and from our acquaintance with its people—is a bulwark against Communism for that part of the world. These four men have come to the United States as representatives of the Thailand State Railway. They spent a month on the New York Central Lines, and they are now in their fourth week of a month on the Milwaukee Road, from where they will go to spend 10 days with the Grand Trunk Western before visting the railways of France, Germany and Holland on their way home.

May I present to you Major Saeng Chulacharitta? Will Major Saeng Chulacharitta please rise? [Applause]

Major Chulacharitta is traffic manager—actually, he is chief operating officer—of the Thailand State Railways.

The next gentleman I would like to have stand and be recognized is Mr. Khun Chamroon, superintendent of construction engineering. [Applause]

And I would appreciate it if Mr. Achava Kunjara, chief of protocol, would stand. [Applause]

And finally, Mr. Ahna Ramyananda, chief officer in administration. [Applause]

Thank you, gentlemen, and you may be seated now. And when you return home, if you send me a leather medal for pronouncing your names correctly, I will appreciate it.

PRESIDENT O'ROURKE: As is readily evident from our program, printed on your pocket registration cards, we still have several important features to come this morning, but I should like to interrupt our proceedings for just a moment to permit the Railway Age to take its usual convention photograph.

Just a moment, please. I have been told that Past President Chinn has just entered the convention hall. Would you please come up here, Mr. Chinn? We want to get you in the picture with us.

[Taking of convention photograph.]

PRESIDENT O'ROURKE: With the thought that those sitting at the speakers' table will be more comfortable in the audience as we continue our program, I will excuse them at this time.

Our next speaker comes to us with a wealth of experience over the years in management–employee relation activities. His lifelong interest and hobby has been in the development of people, adult education, and in pioneering the successful use of labor-management employee suggestion systems. These have included not only employees but all levels of supervision as well.

Seventeen years ago he founded and administered the suggestion plan on the Illinois Central, which ranks at the top of such enterprise nationally. His experience in "dealing with and through people" has extended through large companies with as many as 40,000 employees, on down to as few as 50 employees. Included have been transportation, manufacturing and service organizations.

Upon his retirement from active service on the executive staff of the Illinois Central some two years ago, he embarked upon a career as a consultant and lecturer in management–employee relation activities.

He is well qualified in his field, both by experience and vision, and he knows his way around on our railroads. He has spent much time riding motor cars and walking the property with engineering personnel on several American railroads.

It is my pleasure to present—both as an old friend and as a long-time associate, Mr. Harvey C. Marmaduke, who will address us this morning on the subject, "Building People."

Mr. Marmaduke.

Building People

By Harvey C. Marmaduke

Consultant, Management—Employee Relations

President O'Rourke, AREA Members and distinguished guests. Almost from the time years ago that I went to work as a laborer in the bridge and building department of the Illinois Central Railroad, I have watched and admired the work of AREA. Little did I ever dream that I would one day be on your program. You have made a great contribution to the progress of railroading. I salute you who are here today and those who could not be here.

The annals of AREA contain very little of the human relations aspects of this wonderful progress because "human relations" is not the part of the story that makes headlines. That you deem it important, however, is evidenced by my being on the program this morning. I am happy to be here.

Management News, a publication of the American Management Association, recently quoted Saul M. Silverstein, president of the Rogers Corporation, "The responsibility of

managers" (In my talk today, managers are all who are in the management situation, whether they be chemists, CPA's, engineers, or what have you?) "throughout the world is to recognize the fact that people are the key to all progress and that people are dynamic, not static forces. As such, they can be counted upon to change constantly and, at times, become difficult. But we must never lose our faith in them. This requires humility, tolerance, and, most important of all, understanding."

According to the American Management Association, "Working with, for, and through people is the way in which a manager accomplishes his job. Maintaining good human relations is a manager's responsibility. Providing human satsifactions from work output and relationships is a manager's obligation."

Many management people conceive of "human relations" as just a part of the job, as an activity that can be delegated to some individual or department. Some even think of it as something we can afford in good times and eliminate when the going gets tough. From my observations in commerce and industry over a long spread of years, this is most unfortunate.

In summing up a recent discussion on management, the American Management Association observed, "A manager does not deal with men, money, and materials. He deals with money and materials through *men*. He does not deal with schedules, costs, quality, volume, and people. He reaches his objectives through *people*. His job is not a number of major activities, one of which is human relations. His job is a human relations job that functions through several major activities."

Gentlemen, I certainly have no panacea or magic formula that will make it possible for us to acquire these skills overnight. What I am bringing you today is a summary of observations of things I have seen work, and I hope they will be a contribution. To this end I should like to propose a toast.

May you be DEAF! DUMB! and BLIND!—*Deaf* to shouts of false counsel, but heed the whispers of true opportunities; *Dumb* as a fox, in eluding pitfalls on the way to success; *Blind* to the dim past, but use keen vision for a bright future!

I'd like to tell you about Sam (visual aid:* a picture of five men on an assembly line). For several years, Sam worked alongside other engineers, almost in an assembly line situation. He was an able and reliable worker and had a record of being loyal to his company. In other words, he was a good employee. His good record and ability made him a candidate for promotion to supervisor. And so Sam stepped up one day from a routine research job to a job as a supervisor. His responsibilities mushroomed overnight.

Let's take a look at him as a supervisor (visual aid: enlarged picture of Sam indicating ascendency from the crew). He still is in the same work, but he is interested in more than a single phase of the job. He is interested in people. Five men, five different personalities, report to him. Has Sam changed? He has a new name—"Boss"—and his pay envelope has more dollars in it. But did the promotion carry with it a magic wand, giving him overnight all of the things he will need as a supervisor? Did it make him a leader, a trainer, or adept in developing those qualities in others? I think it is agreed the answer is a loud "No!"

Unfortunately, there are no high-powered glasses that we could set on Sam's nose that would give him all-seeing eyes. I wish there were and that it were possible to put a pair on the nose of every newly made supervisor, in fact, every man in management! Even in this atomic age we all must recognize that it is not possible to manufacture good

* The visual aids used by Mr. Marmaduke during his presentation are not reproduced herein.

leaders. There are a few who are born "naturals", but most must learn by trial and error.

What can be done to help Sam acquire the super-vision he needs as a leader of people?

My feeling is that the positive approach would be to encourage him to study the examples set by other engineers who were expert in leading people—who learned in the school of experience.

The first lesson might be *Study Subordinates* (visual aid: picture of large slate on which is written Lesson No. 1).

Lesson No. 2, *Be Human and Considerate* of others. Learn to like people (visual aid: another slate and the words, "Be human—considerate").

The third lesson is *Delegate Responsibility*. It is a most important part of his growth (visual aid: slate bearing words, "Delegate Responsibility").

Lesson No. 4 is *Let Others in on Plans* (visual aid: another slate). Tell them the how's, the why's and the wherefore's.

Perhaps one of the most important of the lessons is No. 5, *Make People Want to Do Things* (visual aid: slate bearing message).

There are other things that will be helpful to Sam, of course, but I believe these are the five principal guides that will put him on his feet, so to speak. Let's analyze them.

For Lesson No. 1, Study Subordinates, our artist shows Sam literally taking the measure of a man (visual aid). A continuous study of people is a must if he is to get things done through people because people vary so widely. I should like to put them in three classes—*Fits, Misfits, Counter-"Fits."* A *Fit* is the person who just fits into the scheme of things, naturally. He needs no particular attention. A *Misfit* is a square peg in a round hole. Getting him on the right track is management's greatest challenge. A *Counter-"Fit"* is that person who is mentally cut on the bias and imagines he can fool the whole world simply because he can fool himself.

Studying those around him will show Sam that praise may spur one person to great heights. It may only inflate another. Constructive criticism is a tonic for another. He will find there are those, too, who do not respond to either criticism or praise. He will learn to hunt for the things that make his workers "tick", the things that will move them to increased heights of effectiveness. He will learn to search beyond the immediate work situation, too, because people's motives and attitudes are conditioned by personal history and home life.

Sam will find that developing others to succeed him will redound to his credit. He must not get the silly notion that he should blanket the abilities of others to succeed. It works just the opposite, and the degree to which he develops those around him will reflect his own leadership abilities.

Sam's goal should be to become a builder of men (visual aid: picture of man with trowel building a person bigger than himself). The point is that his associates and younger supervisors will use him as a model, whether he recognizes it or not. What he does and what he is have an important bearing on the lives of those around him. So let's caution Sam to remember that the greatest compliment he can earn is to be known as "a builder of men."

The keystone to building such a reputation is to *Be Human* in every-day situations (visual aid: picture of work situation with supervisor first studying and then com-

mending a worker)—I mean in all contacts with those above and below in the management team. In other words, live the Golden Rule. Unfortunately, Sam may not be warmhearted by nature. It is hard for him to be even cordial to certain people and they in turn with him. Sam must recognize this and take steps to warm relations with those around him. How? Among the accepted devices are to use first names, discuss hobbies and not too personal family matters and help others over the rough spots. Sincere moves of this sort will pay dividends in friendships as well as in accomplishment.

Sherman Rogers, in his book "Foremen—Leaders or Drivers," tells of an experience involving Tony, a ferocious person and an impatient worker who was a problem to his boss. Nearly every day he had fights with those around him. A new supervisor, who had been warned about Tony, watched him work one day. Unobserved, he noted the extraordinary care Tony used in doing his work—and some of the things were beyond the call of duty. Impulsively, he walked up to Tony and complimented him on his work. Tony was almost in tears—the boss had said a kind word to him in front of his fellow workers. The next day he appeared on the job with his face washed and in clean overalls. For the first time in years he smiled and met every rebuff or jibe with a pleasantry. The little recognition of Tony's ability made a change in his personality and in his attitude toward his fellow workers. It was a complete reversal in form. Here is a case showing how an unsatisfactory worker was changed through proper handling. Tony continued to develop. He had a fine family. He grew into an excellent citizen and his children were given a college education. A little humanness in this case changed a man's life.

Sam must learn to like people and seize every opportunity to take a sincere interest in the problems of his associates. This means that he will be considerate, which is the essence of being human (visual aid: supervisor counseling with a junior worker).

Author Harvey Stowers has a lesson on the importance of "consideration" in getting things done through people in his book "Management Can Be Human." He said: "Consideration for 'others,' in the deepest sense, is necessary to build team power. Let us always look at it that we are working 'with,' not 'for' or 'under,' others. It spells one big word—teamwork."

I will always remember how just a word of consideration helped me over a rough spot a good many years ago when I was chief clerk to the operating vice president of our company. It had been a tough day and I was on my way homeward. Frankly, I didn't care whether or not school kept. A friend standing next to me in the suburban car engaged me in conversation and said, "Harvey, I was talking to the boss today about ways and means of making greater use of your capabilities. This surprised and pleased me. By then I had reached my station and had to leave my friend. But what a shot in the arm that had been—someone was thinking about me! And someone was considerate enough to tell me about it!

Every-day consideration of others will be reflected in the little things Sam will do. Being courteous to his workers and fellow supervisors is one way. Another is to make his wishes known by requests or suggestions. He will, thus, put himself in the places of workers when making decisions affecting them. He will treat their pride, personalities and self-respect as assets. He will not trample on them.

In other words, if Sam must criticize, he will do it in private, not in public. And most important, he will make the criticism constructive! However, Sam will quickly learn to praise in public (visual aid: picture of man having blue ribbon pinned to his shirt). To give the D.S.C.—Distinguished Service Commendation!—and let the worker know how he is doing. He will do it often but sincerely! And never fail to recognize and

give credit to the one who is responsible and at the same time recognize all who had anything to do with the accomplishment.

The Tony story is an example of what sincere praise will do. There is a Chinese proverb that expresses this truth in a unique way. It is "A single kind word of praise keeps one warm for three winters!" Yes, "A single kind word of praise keeps one warm for three winters."

A most important part of Sam's development is learning to delegate responsibility (visual aid: bandleader and band). He must never try to lead the band and play all the instruments.

We all have seen them, men who have no time for the problems of others, with others idle while they are hard at work late at night in empty offices. And we all have heard them, too, "Route everything through me! I don't dare take a day off! This job is killing me."

Their trouble lies in failure to recognize that responsibility in a management job is far greater than the personal capacity to carry out all details of the job. No one expects the head bookkeeper to check *all* the figures and do *all* the work. No one expects the chief engineer to drive the spikes. Certainly no one expects the company president to personally manufacture, package and then sell his product.

It is important for Sam to learn that successful delegation of responsibility includes (1) spelling out responsibility in a clear-cut manner, (2) fixing limits of authority, (3) keeping control, and (4) fixing standards. In this connection, Harvey Stowers, in the previously-mentioned book "Management Can Be Human", gives us some "do's" for effective delegation. He says:

Do delegate.
Do give subordinates responsibility and let them do it.
Do give him an opportunity to fail.
Do organize your department so it will run smoothly in your absence.

Delegating responsibility is a must, and Sam will not be a good manager if he doesn't delegate just as a man is not a good machinist if he cannot overhaul a machine. Unfortunately, this rule is frequently violated with serious consequences. The manager who keeps his hand in the details of every job discourages the ingenuity of subordinates by competing with them.

The fourth lesson from the school of experience that Sam must learn is the importance of letting others in on plans and programs (visual aid: picture of a conference). Of course there are certain things that he cannot discuss too far in advance. However, it is a good plan for him to discuss changes with those concerned before they are in final form. This makes them a part of the plans. By letting others have a part in making changes, things will go smoother because they will assume a certain amount of personal responsibility for the success of the plan or program. Above all, Sam must learn to give courteous hearing to the ideas of others concerned and *never* ridicule an idea.

No one expects the boss to be infallible. He must be willing to change his mind. If he is wrong, admitting it will gain confidence in his fairness and honesty. Once subordinates *know* that Sam *truly* wants their thinking and ideas, they will be eager to help.

That brings us to the last of our five lessons—Make people *want* to do things (visual aid: men offering to help the boss). What Sam must learn here is best set up by an eminent authority who said, "Workers want a boss who uses a baton—not a club.

They want to be led—not driven. Some supervisors still believe the only way to get workers to do what they want them to do is to drive them. The 'get going, I'm boss—you'll do it my way or else' method will erase the supervisor from the business map faster than any other mistake he might make."

Sam also will have to learn, too, the true meaning of the word leadership—that people do things reluctantly for the driver because he *forces* them—enthusiastically for the true leader because he makes them *want* to follow his wishes. Frankly, I feel that following the previous lessons will make the accomplishment of this one a matter of course.

Essential to his continued progress is the reading of good books and trade magazines to generally keep himself better informed on happenings and developments in his business.

There are three books that have been particularly helpful to me, and I recommend them to Sam. The first one is "Successful Human Relations", by William J. Reilly. The second one is "The Technique of Handling People", by Donald A. and Eleanor C. Laird. The third one is "How To Avoid Work", by Dr. Reilly. The impact of this book is really how to get more out of work. For example:

> *What Is Work?* Most Americans have the ridiculous notion that anything they do which produces an income is work—and that anything they do outside "working" hours is play. There is no logic to that.
>
> I have a friend who is a locomotive engineer. I know he loves the feeling of masterfulness and responsibility that comes over him when he gets behind the throttle and blows that whistle.
>
> But when he comes into his house on a typical night his wife is apt to say, "George, the Carlburgs want us to come over and play bridge tonight."
>
> Suddenly George feels all fagged out. He mutters irritably, "Have we got to go? I've had a hard day. You know I don't like bridge and play it miserably. Besides, Willard is such an old windbag."
>
> Now, to George, playing bridge at the Carlburgs' is the purest kind of work, infinitely more exhausting and harrassing than his activities at the throttle. And he is right.
>
> As we define work in career counseling, it is doing something you don't enjoy doing. You may not enjoy it simply because it bores you, or because you don't have the knack of doing it, or because you have to be with people you don't like. Whatever the reason, you just don't like it. So it is work, even if it's playing bridge at the Carlburgs'.

I want to tell you briefly of a little experience. Not long ago, on short notice, I was drafted to make a talk to a group of 50 or 60 women office supervisors, women who represented a good many companies in Chicago. We had a grand time together. Fortunately, I had two or three spies in the crowd, and I got an immediate reaction to the talk.

Some of these girls said, "You know, that talk makes me think. I wonder what kind of supervisor I am. Do the people around me look upon me as a leader or a stinker?"

Those girls were just taking a mental check of themselves. I wonder if it isn't a good tip for Sam. I wonder if as a manager he shouldn't stand up and take a little walk around himself from time to time and see if he really is measuring up to the standards set for him. Is he alert and fair-minded? Is he developing his leadership abilities?

I rather expect you recognized long ago that Sam is a mythical character. But he could be any one of us. Like us all, he is building for the future. I remember saying earlier that there are no high-powered glasses that we cou'd put on Sam's nose to give him super-vision. Perhaps I was wrong.

If I were a great oculist, I think I could give Sam super-vision by prescribing a pair of bifocal glasses with the distance vision for looking ahead, for planning, and the short vision for the job to be done here and now. Of course he would be cautioned to not work with the vision out of focus.

Here are the ingredients I think I would write into this prescription (visual aid: prescription blank filled in). I would recommend that *Humanness, Consideration and Kindness* be ground into the lenses. Then there would be an ingredient that would give him the ability to delegate responsibility, and he could see the value of studying subordinates and letting others in on plans and programs.

Finally, I would have them grind into these lenses a permanent reminder that a good leader cracks no whip—jabs no needle. He gets things done through people by making people want to do things.

President O'Rourke: Thank you, Mr. Marmaduke, for that thought-provoking address. We shall not forget "Sam." Especially among the younger men listening to you today, if they will only stop to ask themselves how Sam would meet his personnel problems as they go through life, your address will have been worth while. I hope and sincerely believe that many who listened to you today will be better supervisors for having been here.

As escorts for our special guests to participate in the next feature of our program, we have invited to the speaker's table three of our members, or representatives of the Association of American Railroads, who are acquainted with our guests. I should like to present them to you.

Mr. A. L. Sams, office engineer of the Illinois Central Railroad, and chairman of AREA Committee 25—Waterways and Harbors.

Mr. W. H. Hobbs, chief engineer, Missouri Pacific Railroad, and acting chairman of the AAR Committee on Waterway Projects.

I should also like to present to you Colonel Doswell Gullatt, assistant to vice president, waterways, AAR. As many of you know, Colonel Gullatt is a retired officer of the Corps of Engineers, and became connected with the Association of American Railroads in his present capacity during 1955. I am pleased to introduce Colonel Gullatt to you, and in doing so, I shall ask him to introduce our special guests on this occasion.

Doswell Gullatt: Mr. President, members of the American Railway Engineering Association, distinguished guests: This is indeed a pleasure for me to appear before you today. As your president just stated, I have just recently joined the Association of American Railroads. It is unusual that I should appear before you at such an early date, but I do feel very much at home before an engineering organization. I want to say further that I believe I met this man "Sam," a short time ago.

I got on a train going from Washington to Charlotteville, and in due course, I presented my pass to the conductor. The conductor looked at me and looked at the pass, and said, "This pass isn't any good on this train." Well, I felt like I was in kind of a minority group or something because the pass was no good, but he was right up to the occasion. I'm sure his name was Sam because he said to me, "You're going to Charlotteville?" I said, "Yes." I reached in my pocket and said, "I'll pay my way." He told me,

"Oh, I don't know. I hate to see an old railroad man like you pay your way." [Laughter] So I'm sure his name was Sam, and it gave me a very marvelous feeling of being an "old railroad man".

Today I want to present to you some of my old friends of the United States Army Corps of Engineers. We have quite a few of them here from the division and the district, but we won't take time to present all of them now, as I believe we are a little bit behind schedule.

However, I would like to present to you one of my old friends. I say that with a little reservation, because we served together as lieutenants at Belvoir, not too many years ago, but he is now the District Engineer of the Chicago Engineering District. I would like to ask Col. P. F. Kromer to stand. [Applause]

Another old friend of mine is with us today, and he has had considerable service. He graduated from the Military Academy in 1927, and has had considerable service in the Construction Division of the Corps of Engineers throughout the world. He is now the Division Engineer of the North Central Division, with offices here in Chicago. I would like to present to you now, Brig. Gen. P. D. Berrigan. [Applause]

Now I have a real old friend to present to you—Major Gen. Charles G. Holle, deputy chief of engineers for construction, United States Army. As a matter of fact, this gentleman is almost as old as I am. We served together in the early days of Panama —I believe it was our first service outside of the Academy. After General Holle was graduated from the United States Military Academy in 1920, he was graduated from Rensselaer Polytechnic Institute at Troy, N. Y., in 1922. General Holle served throughout the United States, with a great deal of his service in the Mississippi Valley, on river and harbor work, and in the Canal Zone.

When I had lunch with General Holle several days ago, I asked what he wanted me to tell about him. He said, "Well, just don't tell everything." [Laughter] So I won't tell everything, but before I present him to you, I do want to tell you that it reminded me of an occasion that happened not too long ago, when a young lady went up to "Mr. Anthony" and said, "Mr. Anthony, I'm in trouble. I need help. I need your advice."

Mr. Anthony said, "What can I do for you?"

She said, "Well, Mr. Anthony, I'm in terrible trouble. I have a brother, and this brother of mine graduated from two universities, and is an engineer." She didn't say whether he was a railroad engineer or with the Corps of Engineers, but anyhow, he was practicing engineering.

She said, "I have another brother who is over at the penitentiary, and I understand they're going to put him on the 'hot seat' next Monday unless the governor gives him a reprieve. While I was over visiting him, I met another gentleman over there who is going to be paroled, and we're going to be married as soon as he gets paroled. What I want to know is this: Under the circumstances, should I tell my husband-to-be about this brother who is an engineer?" [Laughter]

I just wondered how much further I should go beside saying to you that General Holle, due to the illness of General Sturgis—which is most unfortunate—is now the acting chief of engineers of the United States Army. His career in attaining the permanent position of deputy chief of engineers speaks for itself as to his qualifications as an engineer officer and as a leader of men.

Gentlemen, it gives me great pleasure to present General Holle.

Engineering for Mobility

By Major General Chas. G. Holle
Deputy Chief of Engineers for Construction

President O'Rourke, members of the Association, and your guests: First, I would like to tell Colonel Gullatt that I particularly appreciate his introduction, and appreciate that he is following one of the precepts of Mr. Marmaduke's remarks, and that is to praise in public and to criticize in private.

General Sturgis asked me to bring you his greetings, and to again apologize for his being unable to keep this engagement to address you today. He has had to go to the hospital. It is not an emergency, not a serious operation, but an operation which had to come along, and this was the time it fitted into his schedule, so that I have the pleasure of accepting your invitation and of being with you.

It gives me an opportunity of meeting some old friends, particularly, one of them, your Executive Secretary, Mr. Howard. As Lt. C. G. Holle, I was graduated from Rensselaer Polytechnic Institute in 1922, in the same class as Mr. Howard. I not only claim to be his classmate, but to be in his class.

I also appreciate the courtesy shown to the other officers of the Corps of Engineers who are here.

Now, I claim not only to be representing General Sturgis at your meeting today, but also to being here, to an extent, in my own right, although I don't belong to the American Railway Engineering Association. By virtue of being the Assistant Engineer of Maintenance of the Panama Canal, I had railroad responsibilities in Panama.

I am going to give the speech that General Sturgis prepared. He worked on it personally, and the following are his thoughts.

Since the Corps of Engineers is by far the nation's oldest engineering organization, it naturally has many descendants who have left the ancestral castle. In some cases these descendants have become thriving independent engineering entities that now help to support the parent body.

I believe that your organization, the American Railway Engineering Association, might be included in this category. The Corps of Engineers and its personnel did much of the basic engineering for the nation's railway system. It laid out many of the early eastern lines, and as the rails crossed the Mississippi, laid out all of the great transcontinental trunk lines. It was an Army Engineer officer who built, and for a time managed, the Baltimore and Ohio Railroad. This same officer, Lt. George W. Wheeler, designed the best railway locomotive of his day and was summoned by the Czar of Russia to play a major role in Russian railway development. Up to 1855 the Army Engineers had done the surveying for almost every foot of rail laid in the United States; and after the Civil War the great majority of railway executives were former Corps of Engineers' personnel. It is perhaps for this reason that the railway construction crews in the West were organized along military lines.

Now, though we of the Corps are still vitally interested in rail transportation, and in fact do the maintenance-of-way on some 4000 miles of our own trackage, it is not we but you who are the basic railway engineering authority. Today the Corps of Engineers bases its railway engineering upon the manuals and recommended practice of the AREA. Thus the offspring, grown strong and independent, is helping to support the parent.

The Army Engineers' century-old concern over railway development is due, of course, to the vital relationship between the needs of national defense and the capabilities of the nation's transportation systems. This relationship has many facets, some obvious, some complex. It has never been more important to national survival than it is today.

The Corps of Engineers is directly and importantly involved in the Army's problems of logistics and mobility, and hence directly concerned with the nation's railway transportation system. It is unnecessary, I believe, for me to stress in this connection the vital work of our comrades in the Transportation Corps, with whom we Engineers have been proud to work on many a difficult job from the Arctic to the African deserts. But today I wish to discuss defense transportation problems from the standpoint of our common interest in construction and engineering.

In these days wars may come in all shapes and sizes; and we can deter wars of *all* kinds only if we are demonstrably capable of winning wars of all kinds. Thus our military strength, to accomplish its purposes, must be flexible and proportioned, appropriate to deter or to fight small wars as well as big wars, wars in jungles or mountains, wars in which atomic weapons are used and those in which atomic weapons are not used. As General Maxwell D. Taylor, the Army's Chief of Staff, said recently, "Balanced strength includes the means to put out brush fires promptly before they can spread into general war . . . Our military planning must take into account the increasing reluctance of peace-loving people to embark on general atomic war and giving increasing attention to the constant danger of erosive efforts against weak members of the Free-Nation community".

In other words, our nation's military effort still, as always, involves ground troops and all their gear. Hence it still, as always, involves shifting men about, and hauling great quantities of machinery and equipment, and transporting the vast amounts of raw material needed to manufacture that equipment—in a word, bulk transportation in huge volume on a continental scale.

Even in peacetime, the training and deployment of our troops in the fulfillment of military missions requires tremendous use of railways and other forms of transportation. During the fiscal year 1953 the Army alone—not counting the Navy or Air Force—originated approximately 3400 shipments daily, with an approximate average daily freight charge of more than $1 million. Its own 4000 miles of trackage are scattered at more than 250 separate installations in independent, disconnected units ranging from a few hundred feet to more than 100 miles in length. The fact that we have switching and loading lines in such large aggregate amount is itself an indication of the great reliance of the Army on rail transport. And these peacetime figures give no conception of the use we would have to make of our railway and other transportation systems in case of even a small war.

The heart and core of our defense system is, naturally, our American homeland. Here is where we keep our reserves of strength. This is the starting point of our supply and deployment systems. Here, as nowhere else, we need a super-efficient, expansible network of transportation systems capable of assuming on instant's notice the enormous and absolutely vital responsibilities of wartime mobility.

Mobility in the military sense has two forms—tactical and strategic. Tactical mobility is the ability to shift power on a battlefield. Strategic mobility is the ability to shift power over long distances. It includes the flow and movement of supplies.

Within the United States, railroads are the backbone of our strategic mobility. Those of you who were at work on the railways during World War II—in or out of uniform—have some conception of the vast scope and variety of service demanded by the

Armed Forces in meeting the logistic requirements of wartime. The changes in military planning brought about by the nuclear age will in no wise diminish the need for such services and may well increase them. The tides of battle may shift with greater rapidity about the globe, requiring more movement and transport. We will no longer be able to concentrate men or equipment in congested areas and hold them there until we are ready to move them—not when a single atomic bomb-burst is capable of wiping out a whole concentration area at once. Instead, we will have to disperse our forces in small groups at scattered points, and only at the last moment transport them all together in swift and precisely coordinated multiple movements.

We will have to rely less on congested ports, and hence probably move more material across beaches. This applies not only to combat areas but to the loading and off-loading of vessels at our own shores. And it means that we may well have to have more railroad spurs. We will have to devise means—perhaps portable means—of bringing rail cars to shipside across beaches and exchanging cargoes with a minimum of handling. The Army is already trying out means of transporting railroad rolling stock on rails by the roll-on-roll-off method; aerial tramways to take goods across beaches; new cargo-handling methods; and similar approaches to the problem. Both the Transportation Corps and the Corps of Engineers are involved in this research. Meanwhile, the railroads are making important contributions to the solution of the same general problem with such developments as the "piggy-back" method of hauling truck trailers on flatcars.

Finally, there is the little-considered matter of survival power, which, should we ever become involved in an atomic war, would be the equally important counterpart of striking power. After two nations have struck initial atomic blows at one another, it is the side that can first get to its feet to deliver a second blow which has the advantage, and the one that can keep on standing and fighting longest which will ultimately win. The part which railways play in this ability to survive and fight back was demonstrated in World War II. We hit Germany with thousand-plane raids again and again, and always our enemies were able to move in repair equipment, and shift facilities, and keep on producing and fighting. Only after the allied Armies began to overrun their territory, and we were able to bring our fighter-bombers within range to shoot up locomotives and choke vital arteries of transportation, did Germany's survival power begin to sag. After that, when we smashed a factory, it stayed smashed—reconstruction resources could no longer be brought to the spot. Their survival power no longer matched our destructive power, because they had lost their transport system.

I might add that even under the bombs which fell on Hiroshima and Nagasaki, railroad-type structures stood up among the best.

The destructive power of all major powers has enormously increased since World War II. It may be doubted whether the survival power of any nation has increased in proportion. But with the striking power of each side sufficiently great to do critical damage to the other—as I believe it is—it is the side with the greatest *relative* survival power that is likely to have the decisive advantage. Fully as vital as relative armaments are the relative capacities of the two great powers to reorganize and rebuild, shift and substitute, and swiftly transfer focuses of effort from stricken areas to those more capable of carrying on the struggle. In other words, I believe that flexibility and mobility—construction power and transportation power—are absolutely vital factors in national survival—more so in this atomic age than ever before.

Thus the close bond of interest that has always linked the Army, including the Army Engineers, with the national railway industry is stronger today than ever.

Though we must realistically prepare for it, we all hope and pray that war will never come. But last year it was brought home to us very forcibly that war is by no means the only disaster that can happen to a region or a nation. Great floods occurred within a few months of each other at opposite sides of the country, in New England and in California. I visited both flood areas, and I can testify that the destruction in New England, at least, reminded me of the havoc I saw after World War II. As a result of those disasters, the Federal Civil Defense Administration—which is the agency entrusted with coordinating Federal disaster-relief activities—along with other agencies, is studying ways of better preparing to meet similar disasters in the future. Among other things being considered are the roles to be played by each agency and level of government, the relief and restoration resources available to each, and methods of mobilizing them in a quick and orderly manner.

In case of natural disaster, as in the case of war, the railroads move up from the "necessary" category to the "vital". Railways are needed not only to bring the necessities of existence to the suffering people, but to make possible the swift assembly of the countless tons of equipment and material essential to the rescue and rehabilitation effort. Hence, one of our first tasks in any disaster is always to restore rail transportation and other communications facilities.

The Corps of Engineers has, for well over 125 years, been charged with the federal responsibility for many aspects of our water resources development. Originally the federal interest was only in connection with the improvement of our rivers and harbors. More recently it has included flood control and related functions such as the incidental development of hydro-electric power and provision for municipal and industrial water supply. We Army Engineers have, over this long span of years, studied hundreds of various civil works projects, from the improvement of small coastal harbors-of-refuge to the comprehensive development of our greatest river systems.

These projects have been initiated by people in the local areas who, speaking through their members of Congress, have requested the Corps to investigate the feasibility of solving their water problems. When thorough engineering and economic investigation by the Corps has indicated a solution in which conservatively anticipated benefits will exceed the carefully estimated costs, the projects have been recommended to the Congress. Throughout the years almost 55 percent of the vast number of projects that have been studied by the Corps have not been favorably recommended. This was because an objective analysis indicated that, at least at that time, the benefit-cost ratio was not greater than unity.

The other 45 percent of the projects, that have been favorably recommended by the Chief of Engineers, are required by our established procedures to be submitted twice for review, analysis and consideration by both Houses of Congress. Favorable action is necessary first to authorize the projects as eligible for federal participation—and second to appropriate money for construction. Scrupulous adherence to high technical standards and strict conformance to prescribed legislative processes have resulted in the Corps' civil works program being recognized as making a real and substantial contribution to the safety and economic prosperity of the nation. The program has survived and progressed through depression, war and all the storms and upheavals that have shaken the nation, regardless of which political party was in power. When the second Hoover Commission submitted its report last June, it said "The Corps of Engineers has an enviable record for safe and adequate engineering design. It has demonstrated its ability to carry out very large engineering projects and it has been signally free of any taint

of fraud or dishonesty in the administration of the vast construction program with which it has been entrusted."

The national program for flood protection is, however, only well begun. As our country becomes more crowded and busy with industries producing goods essential to national growth and defense, the necessity of reliable and secure transportation to serve the industrial complex becomes ever greater. And I believe we may well give greater thought to the *prevention* of flood damage to railroads. I believe that the railways, and particularly you railway engineers, can play an important part in better programs for river-valley safety.

From bitter experience, you know as well as we do that the thousands of miles of railroads that parallel our mighty rivers and criss-cross their broad valleys are too often "sitting ducks" when uncontrolled floods are rampant. It is, of course, economically absurd to suggest removing all these railroads from the flood plain or raising them above the level of possible flood damage. However, it is only good common sense to reduce flood risks as rapidly as possible by building soundly conceived and adequately designed flood control projects.

In some cases this can be accomplished by reservoirs—and this almost inevitably involves relocation of some rail facilities. In other cases levees, floodwalls, or channel rectification is the appropriate solution—and again tracks, bridges, switch yards and railroad stations are often involved. In dealing with these problems, we engineers are called upon to find acceptable answers—you for the stockholders, we for the public. Finding such answers has not been easy in the past and I can assure you it will be more difficult in the future. But if American engineers were stopped by difficulty, we would not only have no railroads, we would have no America.

The watchword "keep 'em moving" is virtually as important to our economy as it is on the battlefield. We must neglect no steps that may help preserve the intricate flow of goods and services which sustains our civilization, in all circumstances and through all crises.

The Corps of Engineers shares this responsibility with you because of our responsibility for the nation's navigable waterways. Our connection with waterways has led many people to feel that we are competitors of the railways and are identified with interests adverse to the railways. But in my view, railways, waterways, highways and airways are all indispensable parts of the national transportation system, and the national interest requires all to be in a healthy and thriving condition. For every headlined occasion when railway and waterway interests conflict, there are dozens of unnoticed occasions when their interests coincide and complement and mutually reinforce each other. It has been demonstrated time and again—at Houston, at Kansas City, on the Ohio, along the Gulf—that water transportation tremendously stimulates industry, commerce, and trade in the regions it serves, and that railways share abundantly in the business thus built up.

The requirements of transportation, industry, the Armed Forces, the consuming public, and the many other vital elements of national life keep changing, and each must somehow manage to keep in step, in interlocking operation, with all the rest. This requires an immense, ever-alert cooperativeness which must pervade all our efforts and relations with one another. With the Corps and the railways each respecting the competence, the needs, and the missions of the other, we can provide an example of mutual assistance on the one hand and mutual reliance on the other which is typical of the interdependence of all elements of our unified, democratic nation. I submit that we must

strive to enhance our cooperation—in fact, keep ourselves prepared for the closest integration of effort in case of emergency. Only in this way can we fully discharge our joint responsibilities to the nation's future—whether it is to bring us the peaceful advantages of atom-powered trains, or the holocaust of atomic warfare.

Mr. Gullatt: General Holle, we appreciate your talk very much, and your interest in railroad problems as you see them and as the Corps has to see them. We appreciate your coming here to be with us today. Thank you very much.

President O'Rourke: Thank you, Colonel Gullatt, and thank you, General Holle, for the highly interesting and informative address which you made to our convention in behalf of General Sturgis, who had originally planned to meet with us here this morning. You have made a most acceptable substitute for General Sturgis, and we are happy that you could be with us.

Gentlemen: This completes the program of our opening session. However, before we recess, I would remind you that seven of our committees have scheduled luncheon meetings this noon. The private dining room assignments for the various luncheons are published on the lists which have been made available to you and are also posted on the blackboard located in the foyer just outside of this room. We hope that those of you who will participate in these committee luncheons have already purchased your tickets, but if you have not, tickets may still be purchased from a hotel representative in the 3rd floor elevator lobby.

May I also suggest, if you have not already done so, that you immediately purchase your tickets for the Annual Luncheon which will be held in this room at 12 noon tomorrow. Tickets are avaliable in the foyer. The Annual Luncheon this year, as you know, will be addressed by Mr. Wayne A. Johnston, president, Illinois Central Railroad.

Two more announcements—one about a post-convention feature which may not have come to your attention, since it was developed only as the March issue of the AREA News went to press and could not, therefore, be given adequate attention in the News. I refer to the Ground-Breaking ceremony for the new engineering building to be constructed at the AAR Research Center on the campus of Illinois Institute of Technology. This ceremony will take place at 2:30 pm on Thursday, shortly following the adjournment of our conveniton, and will form part of an Open House at the Research Center, when those members who desire will be the guests of the AAR research staff and will be given an opportunity to see the present two research laboratories at the Center and to witness tests under way. You are cordially invited to participate in this Open House and the Ground-Breaking ceremony. More detailed information concerning this matter, and instructions on how to best get out to the Research Center, are available on printed sheets at the registration desk.

For the second announcement, which deals with a matter of special interest to our structural members, I will call upon C. H. Sandberg, assistant bridge engineer, Santa Fe System. Mr. Sandberg will you please come to the platform and make your announcement.

[At this point Mr. Sandberg invited all members of the Association interested in structural matters to observe caisson loading tests to be conducted Tuesday afternoon near the campus of Northwestern University, at Evanston, Ill., where a 100-ft model truss bridge is to be constructed and tested to determine the behavior and ultimate carrying capacity of truss members].

President O'Rourke: May I remind you that the afternoon session will convene in this room promptly at 2 pm, with a number of interesting reports and special features. May I ask, therefore, that you be back in this room promptly at 2 pm.

The meeting now stands recessed.

[The meeting recessed at 12:20 o'clock].

Afternoon Session—March 13, 1956

[The meeting reconvened at 2 o'clock, President O'Rourke presiding.]

President O'Rourke: The convention will please come to order.

The first report on our program this afternoon is that of Committee 20—Contract Forms, of which W. D. Kirkpatrick, assistant to chief engineer, Missouri Pacific Railroad, St. Louis, Mo., is chairman. Will Mr. Kirkpatrick and members of his committee please come to the platform and present their report?

Before presenting the chairman of this committee to you, I want to invite your comments and criticism in connection with the presentation of each and every report, to the extent that time will permit, and I would point out that a limited amount of time has been provided each committee for this purpose. The year's effort of the working committee is expressed in the Bulletins you have had in your possession for some weeks. The convention should give an opportunity for discussion of these reports. The privileges of the floor are extended to railway officers, engineers, college professors, government officials, manufacturers and supply men, and others who may be or may not be members of the Association. We want anyone to get up who has anything to say on our committee reports.

Portable radio microphones have again been provided for our use through the courtesy of the Motorola Company, and will be made available to you by the hotel bellmen operating in the different aisles. All you need to do is to stand at your place and a microphone will be brought to you. When you have received a microphone, please press the "Talk" button and then talk into the speaker opening, with the microphone about an inch from your mouth. Also, before beginning your remarks, please state your name and railroad.

It is very gratifying to our committees to have their reports bring out full and interesting discussion, and disappointing to them if they fail to produce this result. As a general proposition, everyone loves a good listener, but if we all remain listeners, there will be none to love us.

I now present to you Mr. W. D. Kirkpatrick, chairman of Committee 20, and ask him to conduct the committee's presentation.

Discussion on Contract Forms

[For report, see pp. 347–362.]

[President G. M. O'Rourke presiding]:

Chairman W. D. Kirkpatrick (Missouri Pacific): Mr. President, members of the Association and guests: Your Committee on Contract Forms had four subjects this year, all carried over from last year. These were assigned for study, and I am happy to say that we have reports on all of them. These reports appear in Bulletin 525, starting on page 347.

The first report, on Assignment 1—Revision of Manual, will be presented by W. R. Swatosh, assistant superintendent of construction of the Erie Railroad, chairman of the subcommittee.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman W. R. Swatosh (Erie).

Mr. Swatosh: Mr. President, members of the Association and guests: Review of the Form of Cost-Plus Percentage Construction Contract disclosed that the paragraph pertaining to Independent Contractor is incorrectly positioned, and that Secs. 12 and 13, specifically detailing insurance and indemnity requirements, respectively, needed revamping in order to have this form in general harmony with other similar Manual agreements.

Your committee, therefore, recommends the reapproval of the Form of Cost-Plus Percentage Construction Contract, together with the approval of the changes and additions completely detailed in the report. I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. Swatosh: This completes the report of the subcommittee, Mr. President.

Chairman Kirkpatrick: The next report of the committee is on Assignment 3. There is no Assignment 2.

Assignment 3—Form of Lease Covering Subsurface Rights to Mine Under Railway Miscellaneous Physical Property, is a very involved and complicated form, and has required extensive study by the committee, which study is being continued.

Mr. I. V. Wiley, assistant engineer of the Milwaukee Road, will present a brief progress report on this assignment. Mr. Wiley is chairman of the subcommittee.

Assignment 3—Form of Lease Covering Subsurface Rights to Mine Under Railway Miscellaneous Physical Property, was presented by Subcommittee Chairman I. V. Wiley (Milwaukee).

Mr. Wiley: Mr. President, members of the Association and guests: While your committee does not have a definite tentative form of contract to submit to the Association this year, we can report that we are working on such a tentative form of lease covering subsurface rights to mine under railway miscellaneous physical property and expect to have it ready for the convention next year. This form will be rather long and comprehensive, and we wish to have it in finished shape before presenting it to the membership for study.

This completes the report of the subcommittee.

Chairman Kirkpatrick: This committee has no Assignment 4. Assignment 5 covers insurance provisions recommended for various forms of agreements. As you will see from the Bulletin, this subcommittee has been engaged in gathering information relating to Railroad Protective Liability and Property Damage Insurance, and it is expected that some revision of the various insurance provisions in our contract form will result. Further study is indicated in order that our forms will contain the very best recommended practice with respect to insurance coverage.

Mr. Clarence Young, assistant engineer of the Baltimore & Ohio, chairman of the subcommittee, will present the report.

Assignment 5—Insurance Provisions Recommended for Various Forms of Agreements, was presented by Subcommittee Chairman Clarence Young (B&O).

Mr. Young: Mr. President, members of the Association and guests: The report on Assignment 5 shows the latest developments in the form of railroad protective insurance. Other forms of liability insurance of interest to the engineer are fairly well standardized in satisfactory form, but there is room for considerable improvement in the form of

railroad protective policies. Studies are being carried on by a number of interested associations toward improvement and standardization of this form of insurance. Your committee will endeavor to keep posted and to report any further developments to the Association.

This report is submitted as information.

PRESIDENT O'ROURKE: Thank you, sir.

Proceed, Mr. Kirkpatrick.

CHAIRMAN KIRKPATRICK: Assignment 6 covers the preparation of a form of agreement for turnpike or toll road crossing railway tracks and property. I am sure you will agree that in view of the accelerated toll road construction in this country, this form of agreement is very timely.

In the absence of Mr. Wallenius, chairman of the subcommittee, Mr. E. M. Hastings, Jr., wire crossing engineer of the C&O, vice chairman of this committee, will present the report of the subcommittee.

Assignment 6—Form of Agreement for Turnpike or Toll Road Crossing Railway Tracks and Property, was presented by E. M. Hastings, Jr. (C&O) in the absence of subcommittee chairman J. W. Wallenius (Pennsylvania).

MR. HASTINGS: Your committee has prepared a tentative form of agreement for Turnpike or Toll Road Crossing Railway Tracks and Property. The Manual does not contain a form of agreement covering such an arrangement, and with the great increase in the number of crossings of this type, it was felt desirable to have such a form of agreement.

This agreement, which appears in the Bulletin, is presented as information, and your committee requests your comments and criticism.

This completes the report of Subcommittee 6.

CHAIRMAN KIRKPATRICK: I would like to conclude our presentation by thanking the Association's secretary, the subcommittee chairmen, and all members of the committee for their efforts and splendid cooperation during the past year. We are looking forward to another year of fruitful endeavor during 1956–1957.

Mr. President, this concludes the report of Committee 20.

PRESIDENT O'ROURKE: Thank you, Mr. Kirkpatrick, for your able efforts in behalf of Committee 20 and the Association during the past year. As you know, our Association looks to your committee to keep us up to date on the important matter of Agreements and Contract Forms. You have presented several very important matters to us in your current report, and I know that they will be given the most careful consideration by members of the Association.

Your committee is now excused, with our thanks.

The next committee to make a report is Committee 11—Records and Accounts, of which committee H. N. Halper, valuation engineer, Erie Railroad, Cleveland, Ohio, is chairman. I shall be glad if Chairman Halper and members of his committee will come to the platform and present their report.

Discussion on Records and Accounts

[For report, see pp. 579–642.]

[President G. M. O'Rourke presiding.]

CHAIRMAN H. N. HALPER (Erie): Mr. President, members of the Association and guests: During the past year, Committee 11 lost one of its valued members, who was also chairman of a subcommittee—Mr. A. H. Meyers, assistant engineer, valuation, of the Texas & Pacific Railway. A memoir to him is presented in our report.

Committee 11 had an active year in 1955. We are reporting today on seven of our assignments. A considerable amount of work has been done on each assignment, but we are not yet submitting a report on all of them. I invite your particular attention to the report on Assignment 4, on the use of statistics in railway engineering, and Assignment 5, dealing with the use of electronic tabulating machines in engineering procedures.

I will now call on the chairman of the subcommittee on Assignment 1—Revision of Manual, W. A. Krauska, draftsman of the Missouri Pacific Railroad, to present his report.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman W. A. Krauska (Missouri Pacific).

[Mr. Krauska then read the subcommittee report practically in full.]

CHAIRMAN HALPER: J. H. O'Brien, inspector of accounts, Baltimore & Ohio Railroad, will present the subcommittee report on Assignment 2.

Assignment 2—Bibliography on Subjects Pertaining to Records and Accounts, was presented by Subcommittee Chairman J. H. O'Brien (B&O).

MR. O'BRIEN: Your committee presents a bibliography of subjects pertaining to railroad records and accounts for the period September 1954 to September 1955.

The greater part of this report was prepared by the late Mr. A. H. Meyers, former subcommittee chairman, and consists of 13 subjects under the following general headings: Depreciation; Accelerated Depreciation; Life Expectancy; Cost; Price Level; Research; Machine Accounting; Efficiency of Operation; Rate Regulation; Miscellaneous; Books; Court Decisions; and Depreciation Methods.

CHAIRMAN HALPER: W. M. Ludloph, assistant engineer of the Milwaukee Road, will present the report on Assignment 3—Office and Drafting Practices.

Assignment 3—Office and Drafting Practices, was presented by Subcommittee Chairman W. M. Ludloph (Milwaukee Road).

MR. LUDOLPH: Mr. President, members and guests of the AREA: The report on this assignment is a general summary of the various duplicating processes and brief description of the equipment used in connection with each of the processes.

These processes fall into one of the following general classes, although there is considerable variation in the methods, materials, and equipment used:

(1) Printing
(2) Transfer processes
(3) Photographic reproductions
    A. Contact
        1. Direct
        2. Reflex
    B. Projection
(4) Thermal sensitive paper

Since this report was written, we have been advised that there is a thermal process in which light is also a factor.

This report is submitted as information and it is expected to be rewritten in a condensed form for inclusion in the Manual in the place of the subject "Blue Printing," page 11–1–3, paragraph 20.

CHAIRMAN HALPER: W. M. Hager, valuation engineer of the Southern Railway System, will present the report on Assignment 4.

Assignment 4—Use of Statistics in Railway Engineering, was presented by Subcommittee Chairman W. M. Hager (Southern).

Mr. Hager: Mr. President, Mr. Chairman, members of the American Railway Engineering Association:

From the wide field of possible subjects suggested by this assignment, your subcommittee reports on one practical application for the mass of statistics we develop in our daily operations. The report deals with Budgetary Procedures, specifically with reference to the budgeting and control of all capital and maintenance expenditures in our engineering and maintenance of way departments.

The contemporary railway engineer is a person with diversified talents. No longer does he confine his abilities to the creative design and construction of machines and structures. He constantly seeks answers to the questions "how much" and "why" and he thoroughly searches out all the factors which affect the results he seeks.

In this search he has become proficient in the fields of engineering accounting, cost engineering, methods and systems engineering, statistics, time and motion studies, and the development of cost standards. The statistics developed in these procedures are important tools essential to success in the sciences of engineering and management. They are an important aid in the formulation of new methods and techniques for increasing the quality and quantity of production at a minimum cost.

In our report on Budgetary Procedures we have stressed the importance of reliable statistical data as being essential to the development and enforcement of a sound budgeting system. The report outlines a comprehensive plan for budgeting which we believe embodies all the protective features management might desire. Controls have been outlined to assure compliance with the budget, and a method has been provided for amending the budget to keep it on a current basis.

The report is submitted as information.

Are there any questions?

Question: What is the distinction between cost standards and the budget?

Mr. Hager: In the use of cost standards, it is essential that the distinction between the standard and the budget be understood. Budgets are forecasts of operations, and costs, neither of which should be exceeded. Cost standards reflect typical costs which may be attained under desirable production methods. They are a measure of the time in human and machine efforts converted to dollars for the performance of a unit of work. The unit costs so obtained, multiplied by the quantity of the units to be produced, is the estimated basis for the budget. Both are instruments of control.

If production and cost are held within the limits of the budget, no investigation is necessary. On the other hand, any variance in cost from the standard should be investigated immediately. Costs in excess of the standard will require a correction in production methods. When costs are less than standard, a time and motion study is indicated as the basis for adjusting the standard. Therefore, comparison with well-established standards points the way to increased economies.

President O'Rourke: Any further discussion?

Your report will be received as information.

Proceed, Mr. Halper.

Chairman Halper: W. S. Gates, Jr., assistant to auditor-valuation, Chicago & Illinois Midland Railway, chairman of the subcommittee on Assignment 5, will present his report.

Assignment 5—Construction Reports and Property Records, was presented by Subcommittee Chairman W. S. Gates, Jr. (Chicago & Illinois Midland).

MR. GATES: Our report this year on the use of tabulating machines in engineering department procedures is offered for information only. It was an investigation to determine if these machines might not be useful to the engineering department. During the past few years the tabulating machine has undergone as radical a development as roadway machines with which you are all familiar. The BV 588 return to the Interstate Commerce Commission, Bureau of Valuation, representing an accumulating or an assembling task, lead us to believe that machine procedures might be of material benefit. As indicated on the report an affirmative answer was developed.

Are there any questions?

MR. W. R. SWATOSH (Erie): What could be processed on a tabulating machine?

MR. GATES: As you people may or may not know, the tabulating machine is primarily in the accounting department, and is under the accounting department's supervision. The engineers have not as yet got very far into that field, but there are a great many places where you have engineering studies where you have to assemble a mass of data from a large number of sources, where it can be used to advantage.

For example, a study on the reasons for the replacement of ties over a big railroad system can be put on punch cards, and from them you can isolate the individual incidents and point the way. Of course, the tabulating machine will not lay ties, nor will it do anything, actually, out on the track. Its main function in engineering—as in property records and things of that nature—is to afford you a medium for putting information on to a machine which will produce facts that you can use. It will point out places of weakness. It will point out failures on account of a certain particular item.

I know that you all have a great deal of trouble in getting the necessary amount of clerical help. This machine will save some in clerical help, because it will do the job for you.

PRESIDENT O'ROURKE: Is there any further discussion on this important subject? If not, your report will be received as information.

CHAIRMAN HALPER: H. T. Bradley, valuation engineer, Missouri Pacific, chairman of the subcommittee on Assignment 6, will present his report.

Assignment 6—Valuation and Depreciation, was presented by Subcommittee Chairman H. T. Bradley (Missouri Pacific).

MR. BRADLEY: Mr. President and gentlemen: My remarks will relate exclusively to Assignment 6 (a)—Current Developments in Connection with Regulatory Bodies and Courts.

One of the items mentioned in the report of this subcommittee was the publication of Elements of Value as of January 1, 1954, by the Bureau of Accounts, Cost Finding and Valuation of the Interstate Commerce Commission. Subsequent to making this report, the same Bureau, on February 1, 1956, issued similar elements of value as of January 1, 1955.

Perhaps the most interesting and important subject under consideration by members of Subcommittee 6 is the battle now being waged, in the courts, and elsewhere, to recover the 30 percent deduction for depreciation made by the Internal Revenue Service as a condition precedent to changing from retirement to depreciation accounting for road property. On most railroads the changeover was made at the end, either of 1941 or 1942, and in the aggregate, the 30 percent deduction probably exceeded $1,500,000,000. Possibly

15 to 20 percent of this total has been lost through retirements prior to January 1, 1956, but the residue is still an impressive figure.

In the case of *Commissioner* v *Akron, Canton and Youngstown Railroad Company,* the United States Court of Appeals upheld the Tax Court ruling that a railroad which had not signed a terms letter could not be required to establish a 30 percent reserve. Unfortunately, very few roads are in this category.

In *Denver & Salt Lake Railway* v *Commissioner of Internal Revenue,* the Tax Court held that the 30 percent deduction did not apply when computing obsolescence losses. It is my understanding that this decision is being appealed by the Commission.

Negotiations are being conducted between an AAR committee representing terms letter roads and government officials, including representatives of the Treasury Department and the Internal Revenue Service, seeking to draft appropriate legislation which will afford a satisfactory solution to this problem. One of the proposals being given consideration is to eliminate the 30 percent deduction, but in lieu thereof, set up a depreciation reserve equal to the sum of (a) depreciation sustained prior to March 1, 1913, on property still in existence at the date of the changeover, and (b) depreciation prior to March 1, 1913, applicable to retirements of depreciable property between that date and the date of the changeover where no such deduction had previously been made. In the event no legislation is enacted, it is possible that an adjustment may be made at the administrative level, which will accomplish substantially the same results. In any event, each terms letter road can elect to adopt the proposed statute, or agreement, or continue on the present basis. No recovery for the 30 percent deduction will be allowed prior to the effective date of the election, which will be either January 1, 1954, or January 1, 1955. It is obvious that this proposed plan will have a greater appeal to roads whose property may have been built, or acquired, after March 1, 1913, than to others not so situated.

The report is submitted as information only.

PRESIDENT O'ROURKE: Thank you, sir. It will be so received.

MR. BRADLEY: Any questions?

W. D. KIRKPATRICK (Missouri Pacific): Can you tell me what you consider to be the estimate replacement cost of all properties on railroads in the United States, and what the book value would be?

MR. BRADLEY: Approximately $67 billion dollars. The latest available book value figure, which is from December 31, 1954, was $32.5 billion dollars, approximately.

PRESIDENT O'ROURKE: Are there any other questions on this subject If not, your report will be received as information.

CHAIRMAN HALPER: Mr. M. Friedman, chief valuation engineer, New York Central, chairman of Subcommittee 7, will present his report.

Assignment 7—Revisions and Interpretations of ICC Accounting Classifications, was presented by Subcommittee Chairman Morton Friedman (New York Central).

MR. FRIEDMAN: Mr. President, members of the Association and guests: Since the last report of your subcommittee, the following change has been made in the Uniform System of Accounts for Railroad Companies:

By order dated October 11, 1955(the ICC modified the provisions for condensed classification of operating expense accounts for use by other than Class I carriers, effective January 1, 1956. For the purpose of reporting, the order divides the carriers into two general classes, designated as Class I and Class II. Class I includes all carriers having

annual operating revenues of $3,000,000 or more, and Class II all carriers having annual operating revenues less than $3,000,000. Class I carriers will use the large carrier classification and Class II carriers the condensed classification.

The Annual Report to the ICC on Form A shows in Schedule 515, rails laid in replacement, and in Schedule 516, rails laid in additional tracks and in new lines and extensions. Beginning with the report for the year 1956 the quantities of rails of the various pattern weights, which were formerly reported in gross tons, will be reported in net tons.

In the year 1948 the Bureau of Accounts and Cost Finding (now the Bureau of Accounts, Cost Finding and Valuation) of the ICC proposed four subjects designated as Nos. 423, 424, 425 and 426, which would require radical changes in the accounting and depreciation procedures. The AAR committee, which was assigned these subjcets for study, submitted a report opposing their adoption and transmitted the report to the Director of the Bureau on April 27, 1950. No action having been taken since that date, these subjects were dropped from the AAR committee docket in 1955.

This report is presented as information only.

Are there any questions?

Question (New York Central): Mr. Friedman, I understand that a new accounting classification has been prescribed for the Canadian railroads, effective January 1, 1956. From an engineering and property record standpoint, what are some of the more important differences between the new Canadian system and our ICC system?

Mr. Friedman: The new Classification, which is patterned to a large extent upon the ICC Classification, became effective January 1, 1956, for the Canadian National and Canadian Pacific Railway as they relate to Candian operations. The Board of Transport Commissioners contemplates a condensed classification for use by other carriers operating in Canada, which is to be effective January 1, 1957. We are advised that the condensed classification will embody the same governing accounting principles as the main classification, including those relating to depreciation, replacement and maintenance.

There are some differences between the Canadian and ICC systems relating to the Primary Road and Equipment accounts and to the Maintenance of Way expense accounts, which are not of particular significance. One notable change is the transfer of Account No. 44—Shop Machinery, and Account No. 45—Power Plant Machinery, from the Road to the Equipment block of accounts.

The important differences between the two systems are that the Canadian system eliminates "Betterment" accounting and prescribes depreciation accounting for all Road and Equipment accounts except Land and Unapplied Construction Material and Supplies.

The Canadian system specifies that the Group Plan shall be used for the depreciable property as in the ICC system, but unlike the ICC system, which requires that depreciation charges be computed on the straight-line method, the Canadian system permits the use of the straight-line method or the "user" or unit of production method. The latter method may be quite advantageous in the computation of depreciation for equipment and machinery.

The minimum rule for new or replaced Road Property, except Land and Tracks, is $1000 in the Canadian system, and in the ICC system is $500. For Equipment, the minimum rule is $500 in the Canadian system, and in the ICC system there is no minimum.

Other than the above, there are no important differences in the two systems from an engineering and property record standpoint.

PRESIDENT O'ROURKE: Is there any other discussion? Are there any other questions? If not, your report will be received as information. Proceed, Mr. Halper.

CHAIRMAN HALPER: Mr. President, this concludes the report of Committee 11, and also concludes my term as chairman. I want to express my appreciation to the members of this committee, and particularly to the subcommittee chairmen, for the fine work they have done during my term of office.

I also want to thank the Executive Secretary of this Association, Mr. Howard, for his ready assistance whenever I required it.

I should now like to introduce to you the incoming chairman of this committee, Mr. M. Friedman, chief valuation engineer of the New York Central System. [Applause]. And the new vice chairman, R. B. Aldridge, valuation engineer on the Katy. [Applause.]

PRESIDENT O'ROURKE: Mr. Halper, under your direction for the past three years, your committee has presented many valuable and interesting reports, and your report this year is no exception. I congratulate you and your committee, and I want to take this opportunity to thank you on behalf of the Association for your great contribution in directing the efforts of the committee for the past three years.

We are glad to welcome as the new vice chairman of Committee 11, Mr. Aldridge, and as the new chairman of Committee 11, Mr. Morton Friedman. I am sure that under their direction, the work of your committee will be in good hands for the year ahead.

Your committee is now excused with the thanks of the Association. [Applause]

We will next hear from our Committee 14—Yards and Terminals, of which J. N. Todd—until his retirement recently, superintendent of scales and work equipment, Southern Railway System—is chairman. Will Chairman Todd and members of his committee please come to the platform to present their report?

Again, I would remind the audience that the privilege of the floor will be granted to all members and to interested visitors. I hope, therefore, that you will feel free to discuss the various committee reports as they are presented, especially if you have supplemental information which would be of interest to our membership.

Discussion on Yards and Terminals

[For report, see pp. 363–375.]

[President G. M. O'Rourke presiding.]

CHAIRMAN J. N TODD (Southern, Retired): Mr. President, Committee 14 has six subcommittee reports and two special features. Our reports are to be found in Bulletin 525, beginning on page 363. Our committee has no fear of questions from the floor, and welcomes discussion.

Our first subject is Revision of Manual, which will be presented by W. H. Goold, division engineer, of the New York Central, chairman of the subcommittee.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman W. H. Goold (New York Central).

MR. GOOLD: Mr. President, this committee has reviewed Chapter 14 of the Manual, and has appointed special subcommittees to review sections that appear outdated, with the intention of submitting revisions for this convention to approve in 1957.

In addition, your committee offers for adoption the recommendations found in its report affecting material in the Manual concerning passenger terminals, on pages 14–2–8, 14–2–9, 14–2–13 and 14–2–16 of the Manual.

Mr. President, the committee offers this material for adoption.

[The motion was regularly seconded.]

PRESIDENT O'ROURKE: It has been moved and seconded that the material offered by Mr. Goold be adopted for inclusion in the Manual. Is there any discussion?

[The motion was put to a vote, and carried.]

CHAIRMAN TODD: Our next report involves two related subjects which were assigned to our Subcommittee on Classification Yards. The chairman of that subcommittee is C. E. Merriman of the Santa Fe, who will make the report.

Assignment 2—Classification Yards, Collaborating with Committee 16, was presented by Subcommittee Chairman C. E. Merriman (Santa Fe).

MR. MERRIMAN: Mr. President, members and guests: In the past ten years there perhaps has been no component of railroad properties which has received more attention than yards and terminals, and rightly so. During that time more has been spent building new freight terminals or rebuilding and modernizing old ones than for any other comparable period. However, there are still many outgrown and obsolete yards which offer opportunities for savings and improved service. There is much to indicate that in the next ten years we will see still more activity in providing modern freight facilities.

In 1954 Subcommittee 2 presented a report on nine basic arrangements of receiving and departure yards in relation to hump classification yards. All of the basic arrangements were illustrated by sketches followed by descriptive matter listing the advantages and disadvantages of each in an attempt to aid in the selection of the arrangement best suited for handling a particular type of traffic or to meet the space limitations of a certain location.

Subcommittee 2 now presents a report on the subject, "Track Connections Between Receiving, Classification and Departure Yards" as they relate to hump classification yards.

Although there was agreement among committee members as to the track connections which might be required by each of the basic arrangements reported on in 1954, there was some difference of opinion on the manner of presenting the information. It was finally concluded to handle the matter editorially rather than attempt to illustrate all the suggested track connections on sketches of the basic plans.

This report makes no effort to list all the connections that might apply to each of the nine arrangements, but instead covers, in a general way, such connecting tracks as are usually required, irrespective of plan. From this information it should be a simple matter to select those that apply to a particular layout.

This is a final report, presented as information.

PRESIDENT O'ROURKE: Thank you, sir. It will be so received.

CHAIRMAN TODD: Our Subcommittee on Scales Used in Railway Service has a report in two parts, which will be briefly presented and explained by the subcommittee chairman, C. L. Richard, consultant in industrial weighing.

Assignment 3—Scales Used in Railway Service, was presented by Subcommittee Chairman C. L. Richard.

MR. RICHARD: Mr. President, a year ago this committee presented a report submitting proposed specifications for the manufacture and installation of four-section motor truck scales, and recommended that the specifications, subject to desired revision, be published in the Manual this year. Since no criticisms or revision requests have been received, the committee now recommends that the specifications, with the minor typo-

graphic and editorial changes noted in the report, be adopted and published in the Manual. I do so move.

[The motion was regularly seconded, was put to a vote, and carried.]

MR. RICHARD: Your committee now offers the following as an information report on the subject of "Weighing Freight Cars by the Two-Draft Method." At some 60 locations on American railways, freight cars are being weighed automatically while in motion over short track scales of 12 to 20 ft in length, the total car weight being determined by separately weighing individual trucks and adding the results. Preliminary studies indicate that, with proper installation, maintenance and operation, this method is satisfactory, economical and increasing in prevalence, particularly for weighing carloads of coal, ore, sand and gravel.

The committee intends to continue its study, and plans to report results at a future convention.

PRESIDENT O'ROURKE: Thank you, sir.

CHAIRMAN TODD: We are presenting our second and final report on the subject of Waterfront Terminals this year. It will be presented by the subcommittee chairman, Mr. R. H. Peak, division engineer of the Illinois Central Railroad.

Assignment 4—Waterfront Terminals, was presented by Subcommittee Chairman R. H. Peak (Illinois Central).

MR. PEAK: Mr. President, fellow members and guests: This year your committee continued its practice of reporting on one of the specialized types of waterfront terminals, choosing the ship-to-car handling of bananas as its subject.

The report outlines the various steps to the railroad side of the operation, listing the factors which must be considered in designing a new or remodeled facility.

On page 372 of Bulletin 525, in the second and third paragraphs, there are errors in wording which change the meaning of this part of the report. The words "have the maximum" in the second paragraph and "demands the maximum" in the third should be changed to read "specify a maximum" in the first case and "specifies a maximum" in the second. The sense of the statements should be that the shipper will insist that time from loading to icing and from loading to departure be no longer than a specified maximum time.

Due to the press of other subjects, it is your committee's intention to drop temporarily the study of waterfront terminals, proposing to take it up again as soon as practical.

PRESIDENT O'ROURKE: Thank you, Mr. Peak.

CHAIRMAN TODD: Another subject on which we are submitting a final report of a series is Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars. The chairman of the subcommittee is C. F. Parvin, regional engineer of the Pennsylvania Railroad, who will make the report.

Assignment 6—Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars, was presented by Subcommittee Chairman C. F. Parvin (Pennsylvania).

[Mr. Parvin read in full the printed report on the assignment.]

PRESIDENT O'ROURKE: Thank you, Mr. Parvin.

Mr. Todd, the last three reports have been received as information. Even though they are matters of information, it seems to the Chair that somebody here may have a question or some discussion, and, Mr. Todd, the Chair will welcome any such discussion or questions about these reports.

Is there any such discussion, or are there any questions from the floor, regarding the last three reports? They were reports of importance, and it seems that they should bring forth some discussion. If not, proceed, Mr. Todd.

CHAIRMAN TODD: Our last report is another one which is in two parts, the second part of which I am going to mention first, because we have to dispose of it—Location and Design of Engine Servicing Tracks and Facilities in Relation to Classification Yards. Your committee has included in its program for the present year a review of the Manual material on Locomotives Terminals. In view of this, no report is being made on Assignment 8 (b), and it has been requested that the subject be discontinued. That is in our outline of work.

The first part of that assignment is Location and Design of Car Repair Tracks and Facilities in Relation to Classification Yards, which was prepared by a subcommittee under H. C. Forman, assistant chief engineer of the L&N Railroad. Unfortunately, Mr. Forman is not present today, but the report will be rendered by a member of the subcommittee, Mr. F. E. Austerman, assistant chief engineer of the Chicago Union Station.

Assignment 8 (a)—Location and Design of Car Repair Tracks and Facilities in Relation to Classification Yards, was presented by F. E. Austerman (Chicago Union Station) in the absence of Subcommittee Chairman H. C. Forman (L&N).

MR. AUSTERMAN: President O'Rourke, gentlemen: This report indicates the location of car repair tracks with relation to classification tracks and receiving tracks.

The capacity of the repair tracks is indicated, with a minimum of 55 ft for each car.

Track centers are reported, and the working area between each track is shown.

At the end of the report are listed 12 facilities to be considered in preparing a repair yard in connection with classification yards.

This is a final report, submitted as information, with a recommendation that it be submitted for adoption next year.

PRESIDENT O'ROURKE: It will be so received, Mr. Austerman.

CHAIRMAN TODD: Mr. President, that completes our report. We come now to our special features, of which we have two.

The first is a short movie, entitled, "Via Sevier," which graphically and dramatically portrays the operation of a modern yard.

This morning I discovered a little matter of history which involves a distinguished member of this Association, and I would like to interpolate a few words about that. The yard which is the subject of this picture is on the Southern Railway, in East Tennessee, and it was originally named John Sevier, after the first Governor of Tennessee, who was also a distinguished Revolutionary patriot. It has just come to my attention that our senior vice president, Wm. J. Hedley, and a past chairman of this committee, is a direct descendant of John Sevier—a great, great, great—I don't know how many times—grandfather of his. So it seemed worthwhile to interpolate that statement.

Since the picture has a sound track that explains itself, no further comments are needed. May we now have the picture? [Showing of moving picture.]

[Vice President Wm. J. Hedley assumed the chair.]

VICE PRESIDENT HEDLEY: That was a very interesting picture, Mr. Todd, and thank you for making this occasion a bit of my family history. Proceed.

CHAIRMAN TODD: If there are no questions about this feature, we will proceed to our second special feature. It is a paper on electronic weighing of freight cars in motion, and some newly collected data are to be presented. The scale is at the Kirk Yard of the Elgin,

Joliet & Eastern Railway, and the paper is to be presented by Mr. Verne C. Kennedy, president of Streeter–Amet Company, supplier of the scale. Mr. Kennedy is a distinguished man in his field, a graduate of Massachusetts Institute of Technology, and is currently president of the National Scalemen's Association. I take pleasure in presenting Mr. Kennedy.

Electronic Weighing of Freight Cars in Motion

By Verne C. Kennedy
President, Streeter-Amet Company

Weighing freight cars in motion, with automatic determination and recording of their weight by mechanical means, has been accepted practice on American railways since the year 1888. The application of electronic principles and instruments for the same purpose is a modern development which began in 1949 and is only now emerging from the "proving ground" stages of experiment and trial use.

The phrases "electronic weighing" and "electronic track scale", when they were first used, seemed to provoke the hopeful interest and expectations of railway operating officials concerned with the weighing of moving freight cars rapidly and with requisite accuracy, particularly in modern high-speed hump yards. However, up to the present time there has been reported no factual or comprehensive data to indicate whether such facilities fulfill expectations or requirements as regards their comparable accuracy, consistency, and general utility.

My purpose, in this presentation, is to describe some extensive tests and studies conducted recently on one electronic scale used for weighing cars in motion, and to report and analyze the information obtained. The data to be reported were collected jointly by the Elgin, Joliet and Eastern Railway, which uses the scale, and the Street–Amet Company, which designed and installed the electronic weighing system. The tests were conducted under the supervision of the Western Weighing and Inspection Bureau, and were witnessed by representatives of that agency and by others having an interest in the studies. All data obtained during the course of the tests have been made available to Committee 14 of this Association.

A brief explanation of the basic design and operation principles of a so-called electronic scale is appropriate. Actually, the term "electronic" applies only to the instrumentation, and is not truly descriptive of the scale. "Load-cell scale" is the preferred term, inasmuch as load cells instead of levers are the primary weight measuring components.

A typical load cell, illustrated in slide 1, represents a form of electric strain gage device which acts as a transducer to convert applied load forces into electric signals—the strength of the signal (voltage) being directly proportional to the magnitude of the load force. By means of wires carried in conduit, the signals are transmitted to the instrument assembly which may be located at any convenient adjacent or remote place.

Incorporated in the instrument assembly (slide 2) are the elements which receive the signals, amplify them, and cause them to actuate electro-mechanical units that print appropriate weight values in digital form on a scale ticket, as illustrated in slide 3, or on tape or other record forms.

The circuit system for the load cells and instrument components are shown in diagram form in slide 4.

The particular load-cell scale which was the subject of study is located in Kirk Yard of the Elgin, Joliet and Eastern Railway at Gary, Ind. Slide 5 shows the yard lay-out

Slide 1.

Slide 2.

OFFICE COPY

[redacted]

Phones { CEN tral 9488
ROC kwell 9488
La Grange 12

General Offices:
111 W. Washington St.
CHICAGO, ILL.

No. 51079 Date_____ 193____

To PRINTED WEIGHTS ARE YOUR PROTECTION

UARCO E-Z-OUT FORMS

USED WITH STREETER-AMET
AUTOMATIC WEIGHT RECORDER

Produce legible manifold copies
as shown by this sample.

Trucked by_____

This is to certify that the following described material was weighed by a licensed and bonded weighmaster of the City of Chicago and his seal and signature attached hereto, certifies to the accuracy of the recorded weights as prescribed by Chapter 67, Article XXVI, of the Revised Chicago Code of 1931.

_____ { Deputy Public Weighmaster

Kind of Material	Gross Weight_____ Tare Weight_____ Net Weight_____

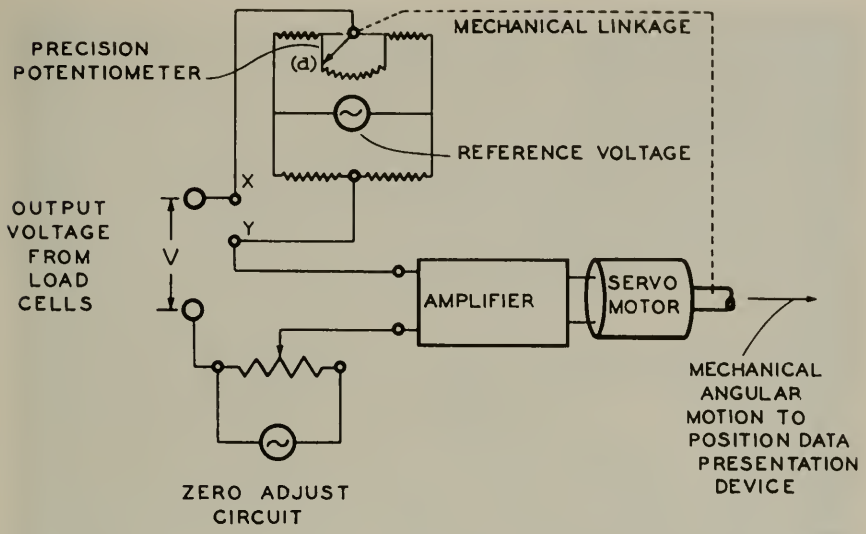
Received by_____

Slide 3.

with the hump and scale. The scale proper is 50 ft from the hump apex, with the weigh rails 90 ft long on a 3 percent gradient.

Mechanical Stability

The weighbridge supporting the weigh rails is mounted upon eight pairs of load cells which, in turn, are mounted upon the main levers of a conventional type track scale equipped with a manually operated weighbeam. (Slide 6 and 6a). Thus the installation comprises two independent weighing systems and permits the weighing of a car



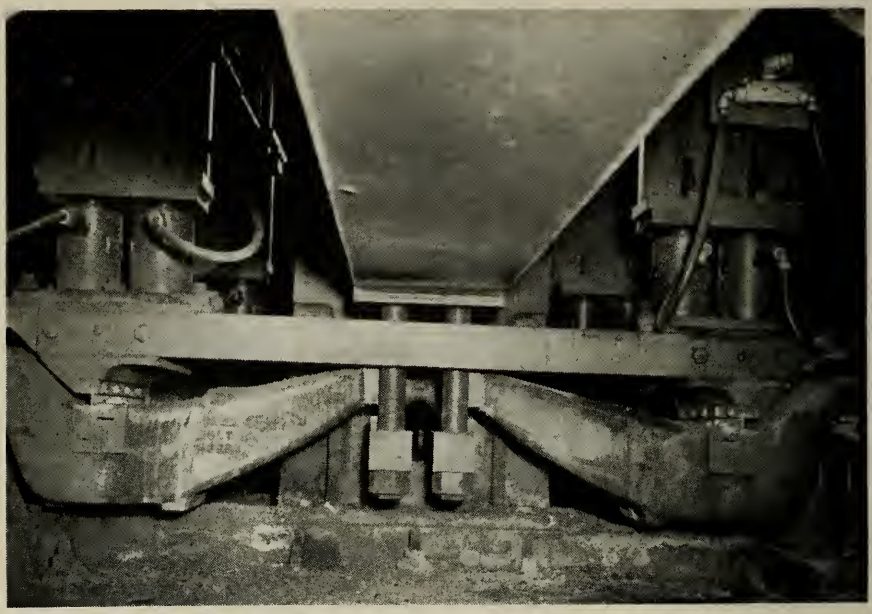
Slide 4.

Slide 5.

either manually on the lever system and weighbeam, or automatically on the instrumented load cell system.

As illustrated in slide 7, the weighbeam of the lever system and the instrument console of the load-cell system are installed within the same scale house, a circumstance which facilitated comparative weighing on the two systems during the studies.

The study here reported began on October 17, 1955, with an initial test and calibration of both weighing systems. Standard weight test cars (slide 8) representing known-



Slide 6.

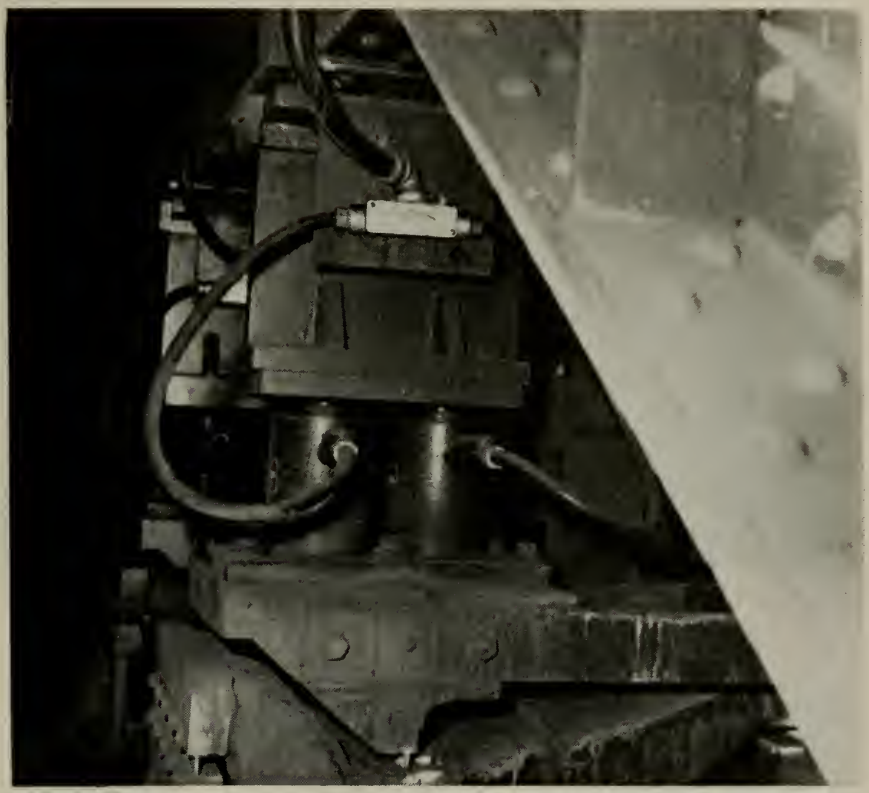
value test loads of 60,000 lb, 80,000 lb, and in combination 140,000 lb, were placed at appropriate positions on the weigh rails, and the weight values indicated on each weighing system were observed and recorded. Eleven separate observations were made on the lever scale, and 22 observations were made on the load cell scale.

The results of this first test are plotted on slide 9 to show the range and mean value of the errors in each weighing system under each test load. The diverging solid and broken lines represent the critical "acceptance tolerances" applicable to the scales on their first test (1/20 of 1 percent).

It will be seen that the mean errors for both systems are well within the applicable acceptance tolerances, that the maximum error for the load-cell system is 100 lb, which is the value of the minimum weight print interval, and that the mean errors for the 2 scales at any load differ by less than 50 lb.

Following the initial tests with standard weight loads, seven road cars ranging in weight from 43,000 to 192,000 lb, and in length from 40 to 65 ft, were weighed on the lever scale while stationary. They were then humped at normal speeds 7 successive times, and their weight values automatically recorded on the load-cell system at the end of 3 sec scale-borne time. (Due to the hump geometry, the time was reduced to 2.5 sec for two 65-ft cars.)

A total of 43 running weight values were recorded on the load cell scale. On slide 10 are shown the range and mean value of the weight difference for each car. For reference, the applicable "maintenance tolerance" for scales in use is represented by the diverging broken lines. Significant features of the plotted data are that the mean weight difference for each car is well within the maintenance tolerance and that only 2 of the 43 differ-



Slide 6a.

ences exceed, by very small amounts, that criteria. It is also of interest to report that the average error per car was in the low order of — 29.8 lb, that in three instances there was zero weight difference, and that the numbers of plus and minus weight differences were equal.

The foregoing comparisons were made with the automatic weight recorder of the load-cell system set for 3 sec scale-borne time. For information regarding possible effects of running speed on weighing accuracy, 21 additional observations were made with sensing time reduced to 2.5 sec.

On slide 11 are compared the weight difference range and average for each car at the two running speeds. Although the data may not be sufficiently comprehensive to warrant conclusion, they indicate that a running time of 2.5 sec may be adequate for the installation under discussion.

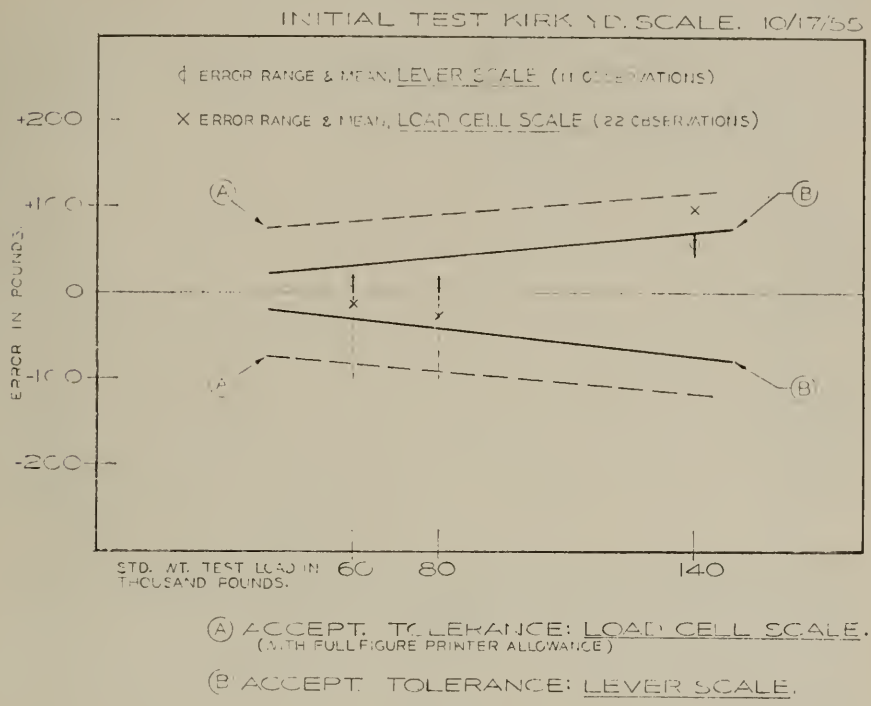
To supplement the studies already reported, a series of weekly weighing comparisons was made during the months of November and December 1955. Four hopper cars, empty or loaded with slag, were utilized—the weekly procedure being to weigh each car stationary on the lever scale and subsequently weigh it automatically several times while

Slide 7.

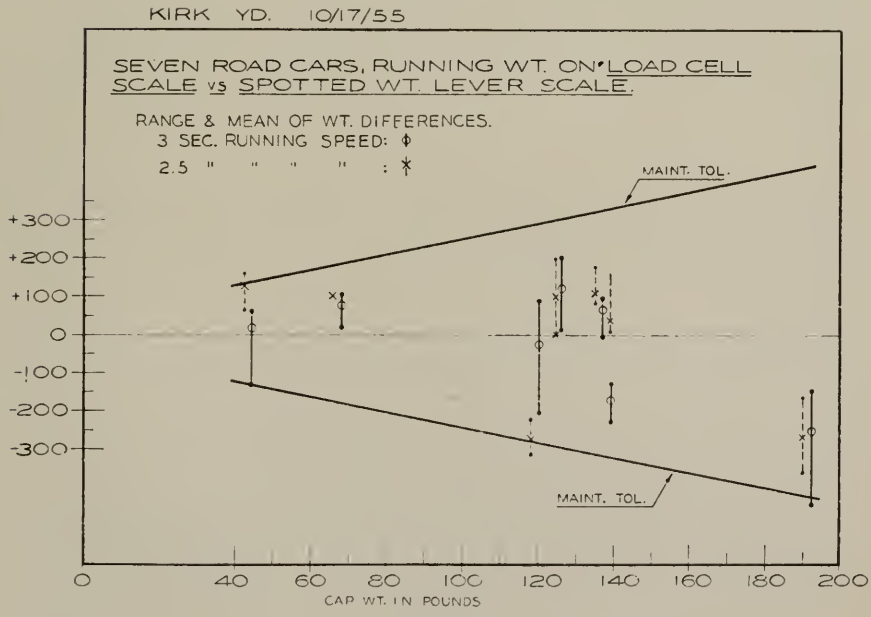
Slide 8.

in motion on the load-cell scale. Forty-one such comparisons were made up to November 21, and combine with the 64 earlier comparisons to represent a total of 105 comparative weighings.

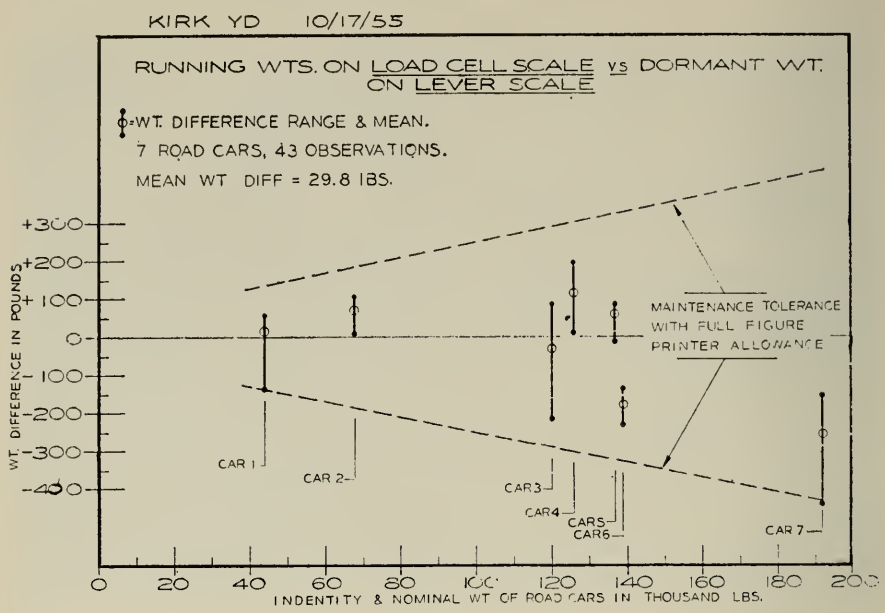
For analysis of these data statistically, each weight difference was converted to equivalent percentage of car weight, and the resulting values plotted to show the frequency distribution as shown in slide 12. Although the values do not assume the pattern of a normal error curve, it is probable that this is due in part to the limited amount of



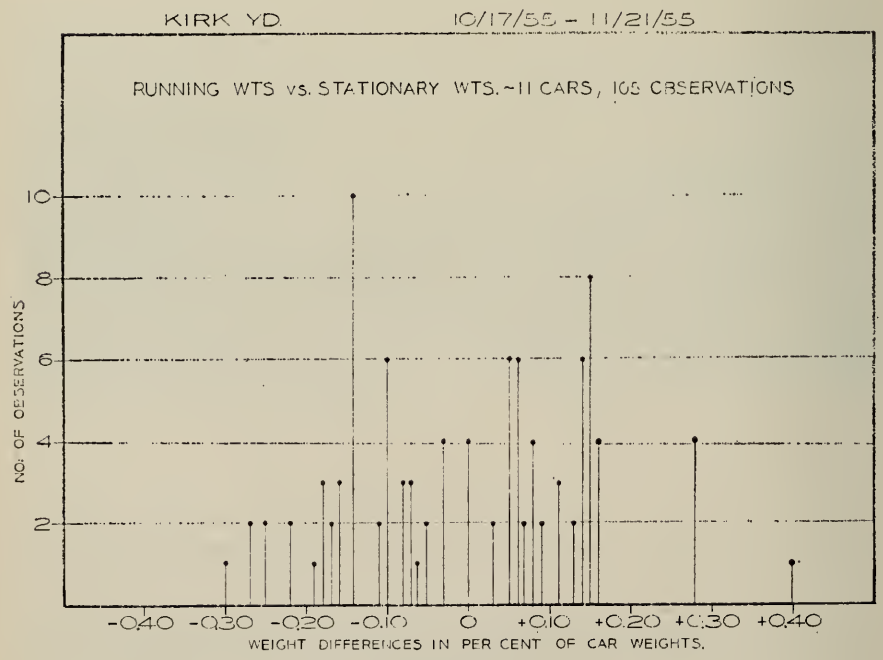
Slide 9.



Slide 10.



Slide 11.


KIRK YD. 10/17/55 - 11/21/55
RUNNING WTS vs. STATIONARY WTS. - 11 CARS, 108 OBSERVATIONS
NO. OF OBSERVATIONS
10
8
6
4
2
-0.40 -0.30 -0.20 -0.10 0 +0.10 +0.20 +0.30 +0.40
WEIGHT DIFFERENCES IN PER CENT OF CAR WEIGHTS.

Slide 12.

data collected, and in part to incompatibility of weighing precision in the two systems, the lever scale registering in 20-lb intervals, and the load-cell scale in 100-lb intervals. Regardless of that consideration, it is significant that 95 percent of the weight differences were less than the variation allowed the load-cell scale for weighing a load at rest, that the average weight difference for all comparisons was only 40 lb, and that the differences had a plus sign in 48 cases, a minus sign in 53 cases, and had zero value in 4 cases.

One month after the studies were begun, the separate systems were again tested with the standard weight loads of 60,000, 80,000, and 140,000 lb. The test results showed no significant change in the accuracy of either system, and demonstrated that each had maintained its initial calibration. In that same connection, it is to be noted that during the period of the studies reported, no equipment adjustments or modifications were made, except for the usual occasional adjustment of zero balance on each system.

As a supplementary study, during the period October 17 to October 21, a 72-hr continuous comparison was made of running weights recorded by two independent means. (Slide 13). For the purpose, the weights of cars passing over the scale rails were recorded automatically by a mechanical device connected to the lever system, and also by the recording instrument of the load-cell system. (In some cases the load cell weight was compared with spot weights obtained at car destination).

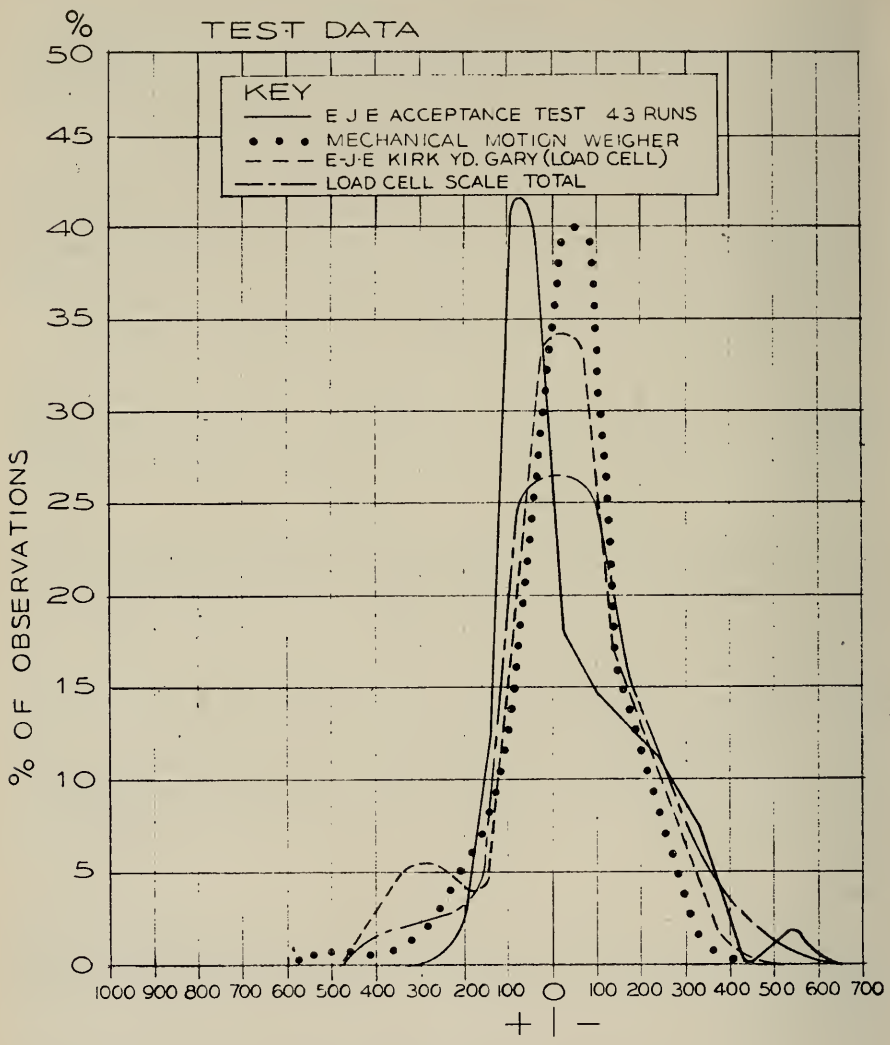
It was reported to the Western Weighing and Inspection Bureau that: "the weekly tests were run between October 31, 1955, and January 30, 1956, in which you will note there were 169 running tests made during the period, 88 of which were minus and 81 of which were plus errors. Minus errors amounted to a total of 18,340 lb, and plus errors to 10,270 lb, for an average of 8,070 lb minus. This is an average minus weight of 47.75 lb per car. Total errors on which cars exceeded 0.2 percent allowable tolerance amounted to 24, of which 14 were on the minus side, averaging 127.7 lb, and 10 were on the plus side, averaging 155.8 lb per car. Four of these errors occurred during the first 88 running tests, and the balance of 20 occurred during the next 69 tests, with none in the last 12 tests. Some of these errors are known to have been caused by cars spilling material because of bumping in the retarders and being allowed to run down into the yard and bump other cars."

Summary

Although the tests and studies are being continued to develop additional data, it is believed that the information collected thus far warrants some specific conclusions regarding the particular installation studies, and some generalizations concerning load-cell track scales as a type.

1. The load-cell weighing system at Kirk Yard, with the improved instrumentation developed by Streeter–Amet Company and the Elgin, Joliet and Eastern Railway, permits freight cars to be automatically weighed in motion without sacrificing essential accuracy for operating speed.

2. The satisfactory performance of the Kirk Yard load-cell scale demonstrates the efficacy of a new instrumentation feature which was specially developed for the installation, and which automatically senses and anticipates the total weight of each car as successive pairs of the car wheels are received on the scale rails. This new approach, a principle widely employed in electronic applications for military use, gives promising indication that future developments may significantly reduce the time required for motion weighing.



Slide 13.

3. It is gratifying to be able to report that throughout the period of the studies and tests here reported there have been no failures or breakdowns of any components of the Kirk Yard load-cell scale. Nor, except for occasional correction of zero balance which is common to all weighing machines, were there any corrective adjustments necessary.

4. It should be understood that the final and successful solution of the problem at Kirk Yard was realized only after expenditure of much time and money for experimentation, research, engineering study and development of new instrumentation. It was found necessary, for example, to develop special means and equipment for excluding moisture

from parts, eliminating the effects of stray electric currents, grounding circuits, shielding conduit cables, etc. These, and other factors, depending upon conditions at each installation, are to be expected as trouble sources in any load-cell scale, and require special treatment if they are not to affect weighing accuracy and consistent performance.

5. It is to be realized that although all information pertinent to the studies discussed have been reported to you and filed with your Committee 14, the data relate to but one scale, produced by one manufacturer, and operated by one railroad. I suggest that, for the benefit of railroads contemplating future procurement of load-cell scales, and for the general information of the Association membership, corresponding studies and tests be made of other installations on other railroads, and the information supplied to the Association during this coming year.

In final conclusion, I wish to express my personal appreciation of the capable and willing cooperation extended during these studies by Mr. S. H. Shepley, chief engineer, Elgin, Joliet and Eastern Railway, and his staff.

Chairman Todd: Thank you Mr. Kennedy. Are there any questions? While this is a highly technical paper this is an association of engineers, and I am sure you must have some questions in your minds concerning his presentation.

Mr. Kennedy, the American Railway Engineering Association appreciates your part in this program, and I'm sure that the data you have presented, and your comments thereon, are an important contribution to the literature of this Association.

Mr. President, I regret that we ran over a little bit, so we'll get along as fast as we can. That concludes the work of Committee 14 for the year just passed, and it also concludes my term as chairman. Before introducing my successor, I would like to pay tribute to the members of the committee, whose loyalty, energy and constant attendance have contributed so much to whatever success we may have achieved in our work.

Our new chairman is F. A. Hess, division engineer of the Indiana Harbor Belt Railway (NYC), a man well qualified by experience and service on the committee. May I present Mr. Hess. [Applause]

Our new vice chairman is A. S. Krefting of the Soo Line, who has been a diligent and faithful worker. Mr. Krefting. [Applause]

Vice President Hedley: Thank you, Mr. Todd. It is a real personal pleasure for me to thank you. As a member of this committee for many years, I have come to know its members probably better than most of the AREA membership.

The reports of your committee, Mr. Kennedy's address, and the Southern Railway film on the modern Sevier hump classification yard, have been highlights of our convention program. In extent and variety, you have put on a veritable three-ring circus which has been most interesting to all of us.

It is with a great sense of appreciation that we look back over the last three years of work by your committee under your direction. We welcome as your successor Mr. F. A. Hess, and as your new vice chairman, Mr. Krefting. I am sure these two men will ably progress in the year ahead the work which you have directed so ably for the last three years.

And, incidentally, may I wish for you many years of health and happiness in your retirement from active railroad service.

Your committee is now dismissed with the thanks of the Association. [Applause]

The next committee to report is Committee 16—Economics of Railway Location and Operation. Mr. H. B. Christianson, Jr., assistant chief engineer, Chicago, Rock Island &

Pacific Railroad, is completing his first year as chairman of this important committee, and I should be glad if he and members of his committee will come to the platform to present their report.

While the committee is coming to the table, may I again remind you that comments and discussion are invited from the floor in connection with each of the separate reports of the committee.

Discussion on Economics of Railway Location and Operation

[For report, see pp. 313–324.]

[Vice President Wm. J. Hedley presiding.]

Chairman H. B. Christianson, Jr. (Rock Island): Mr. Hedley, gentlemen: Committee 16 has completed another active year, having met in Chicago, Milwaukee, Wisc., and South Bend, Ind. Today we report on three of our eight assignments, and they are all controversial assignments. All our reports are published in AREA Bulletin 525, for November 1955.

Our first report is on the Yager formula. Chairman of the 10-man subcommittee is J. P. Ray, regional engineer, B&O, Cincinnati, Ohio.

Assignment 3—Revision of Yager Formula, Collaborating with Committee 11, was presented by Subcommittee Chairman J. P. Ray (B&O).

Mr. Ray: Mr. Chairman: Your committee has recommended that the "Yager Formula" be removed from the Manual. For some time there has been dissatisfaction with the so-called Yager Formula. As early as 1948, Committee 16 received numerous requests to withdraw or amend the formula. As you know, the principal use of the formula was to establish a "method for the determination of proper allowance for maintenance of way expense due to increased use and increased investment."

An outline of the deficiencies of the Yager Formula may be briefly stated as follows:

The method popularly known as the Yager Formula, made the following reservation as to its use:

> "In the present state of knowledge it is not recommended that the following method be applied to a condition where the variation of traffic exceeds one-third above or below that of the base period. Used judiciously within this limitation the method will give reasonably accurate results if applied to a property sufficiently large or to a period of sufficient time to permit of the smoothing out of irregularities due to accidental conditions."

This formula was devised over a third of a century ago. Conditions have changed to a point where it is no longer applicable since large increases in traffic have been experienced; change from steam to diesel power in a great measure has taken place; improved materials have been developed; technological advances have been made in maintenance work; and branch line mileages have been abandoned. With the heavy increase in traffic experienced during and subsequent to World War II, it was found that maintenance was affected to a greater extent by usage than by mileage and, therefore, usage is a more important factor in maintenance expense.

A large part of the subcommittee's work in the first period consisted of an attempt to bring the table of percentages affected by use into line with present-day thinking. That, of course, led to a study of principles by which determination of those percentages were made in the first place. The method was found to be a concensus based on experience

of those charged with the study. No scientific basis of making that determination has so far been found.

The first draft of a revision of Yager Formula was made February 15, 1952, and found unsatisfactory. Draft No. 2 of a revision of the formula was prepared on June 10, 1952. Draft No. 3 was prepared on January 12, 1953. Draft No. 4 of the formula was prepared in January of 1954 and was discussed at the 1954 March meeting of the AREA.

During June of 1955 representatives of Committee 11 and Committee 16 met at Chicago and made the following joint recommendation:

"Remove Yager Formula from Manual of Recommended Practice . . ."

Committee 16 approved this proposal in prescribed form by a practically unanimous vote. Committee 11 has indicated its approval of that recommendation.

I move its adoption by the Association.

[The motion was regularly seconded, was put to a vote, and carried.]

CHAIRMAN CHRISTIANSON: Are there any questions about this Yager Formula?

This was a progress report, recommending withdrawal of Manual material. Where do we go from here? We know at least three methods of office analysis of deferred maintenance. One would be a new kind of formula, simpler, more flexible and more usable than before. Another would be the simple correlation method developed for us by E. C. Poole of the Southern Pacific, which has given surprisingly accurate results. Another would be the curve suggested by T. A. Blair of the Santa Fe, which charts costs per gross ton-mile for various levels of traffic. There are other methods. To find the best, we need your help and the continued support of Committee 11.

Our next report concerns trailers on flat cars. The chairman of the 14-man subcommittee handling this assignment is F. N. Nye, director of transportation and economic research, New York Central.

Assignment 4—Economics of "Highway Trailers on Flat Cars" Service, Collaborating with American Association of Railroad Superintendents, was presented by Subcommittee Chairman F. N. Nye (New York Central).

MR. NYE: Mr. Chairman, members of the Association, and guests: This is a final report, submitted as information. Last year we reported briefly on the background of trailer-on-flat-car operations and on recent developments.

This type of traffic is being handled by more and more carriers; its volume continues to expand. Its growth has been consistent but not spectacular.

For those interested in current activities, reference should be made to the December 5, 1955, issue of Railway Age, to the December 1955 issue of Modern Railroads, and to the January 1956 issues of Railway Freight Traffic and Railway Progress. These publications report new developments as they occur.

Our concluding report deals with the essential requirement of ascertaining the cost of providing the service and so establishing a basis for publishing rates if the service is provided under rail tariffs, or to negotiate divisions of rates if it be accorded under motor carrier tariffs as a cordinated service.

Cost determinations on a railroad—confronted increasingly with both highway and waterway competition—must of necessity become of controlling importance. The old value-of-service theory will in the future, we believe, be forced to a secondary status. Competitive rates as published today are frequently subject to protest by the "aggrieved carrier" and are often suspended by the Interstate Commerce Commission. To justify

them before the commission it is essentiai to prove them compensatory, at least on an out-of-pocket basis, and to show further that they make some contribution to overhead or fully distributed costs. If a railroad defendant is not prepared to submit forthright and logically constructed cost figures, the commission or the protestant will rely on statistical data and methods of a complicated and confusing nature, which will prejudice and perhaps defeat the railroad's legitimate effort to meet its competition.

Cost finding is a difficult procedure—and perhaps a dangerous business—but railroad management can not evade its responsibility honestly and aggressively to meet its competition and to do so at a profit. It is better, we believe, to prepare freight costs in the light of actual experience and with an understanding of the proposed operation, than to have the opposition becloud the issue by alleging costs which are compounded from system-wide averages predicated on all services—both freight and passenger.

It is the committee's view that primary costs should be developed on an out-of-pocket basis and be related as closely as possible to the specific movements under study. They should reflect all major groups of accounts, that it, *Maintenance of Way*—particularly the expenses required to make good the wear and tear on the track and terminals; and *Maintenance of Equipment*—as to the cost of repair and upkeep on locomotives and equipment assigned to or required by the service. *Transportation Costs* must include engine and train crew wages; fuel, lubricants and supplies; broken down as to line haul, yard and terminal swtiching. Terminal costs for loading and unloading the trailers must be included, which costs may vary widely depending on the type of equipment used and on the design and adequacy of the terminal facilities. Billing and accounting costs must be included too.

To establish a trailer-on-flat-car service, some investment is usually required in terminal layouts. There will also be expenditures for special equipment or for modification of existing equipment to make it suitable for the operation. The capital cost of such facilities and equipment must include interest on the investment, amortization and/or depreciation, increased taxes, etc. There will also be capital costs charged against the power assigned to or required by the proposed operation.

These operating costs and capital charges must then be prorated to service units, i.e., train miles, car miles and trailer miles.

The committee's report also includes a method for ascertaining a reasonable charge to cover return on investment in tracks and right-of-way.

This concluding report is submitted to illustrate one method of evaluating this problem. Each railroad developing cost data for such a service must, of course, rely on its own statistics and cost factors, and apply them in a manner consistent with its physical characteristics and proposed method of operation.

This report, as stated, is a final report, submitted as information.

Chairman Christianson: Along with the expansion of "piggy-back" are the current "fishy-back" ventures of motor and water carriers. So far, no one has attempted "birdy-back".

Gentlemen, Mr. Nye's cost analysis of trailer-on-flat-car service is the best and most concise report I have seen. It is second to none, and I think you can use it in your company.

Next, we report on Assignment 5. It has the imposing title, "Comparison of running time with total time between loading and unloading points of freight cars, and methods of reducing total time, collaborating with Car Service Division, AAR, Signal Section, AAR, Communications Section, AAR, and American Association of Railroad Superin-

tendents." Boiled down, this means "how to reduce loaded car time." This and its corollary—how to reduce empty car time—are the essence of railroading.

Chairman of the 14-man subcommittee is J. Edward Jay, transportation economist for the federal government, assigned to distribution research in the Department of Agriculture. He was formerly train dispatcher for the Katy and the Southern Pacific.

Assignment 5—Comparison of Running Time with Total Time Between Loading and Unloading Points of Freight Cars, and Methods of Reducing Total Time, was presented by Subcommittee Chairman J. E. Jay (U. S. Dept. of Agriculture).

Mr. Jay: Mr. Chairman, ladies and gentlemen:

The first phase of Assignment 5 is to compare the time that the average carload is moving in trains, with its total transit time. Thereafter, the second phase will be to analyze methods of reducing total transit time.

The samples of carload movements obtained by the committee were from the records of individual railroads, and consequently, showed only part of the longer average haul for carloads that are interchanged between railroads. The AREA data on an individual railroad basis were analyzed and compared with similar transit time surveys, but including interchanged traffic, made by others several years ago, including the one-day analysis by the Federal Coordinator of Transportation in 1933. Although our data were not fully comparable, they were adequate to illustrate the problem. That analysis was reported in Bulletin 525 last December.

The committee later compared its data with the 1955 freight train performance figures recently reported by each railroad to the ICC. The later figures were averaged for 42 railroads, each having over 1000 miles of road. These 42 railroads handle over 90 percent of the loaded car-miles. Compared with current figures, and now on an individual railroad basis, the AREA data are fairly representative of carload movements last year.

The most significant information obtained from the AREA samples is that the average carload requires 82 hr to complete its average haul on one railroad; and is in a moving train 11 hr of its 82 hr, approximately 14 percent of the transit time. That ratio of 14 percent is a tentative answer to the first phase of Assignment 5.

The 42 largest railroads had an average haul last year of 286 miles per railroad, the same as AREA data. Their freight trains averaged 26 miles-per-hour, omitting train hours in train switching, also the same as AREA data. It can be assumed, therefore, that the average carload handled last year required 82 hr for its transit time, and was actually moving 11 hr. In other words, it takes approximately 3.5 days for a carload to move 286 miles, at the rate of 80 miles a day. When one carload is in a moving train, 6 other carloads will be awaiting movement.

The average of 80 loaded car-miles per loaded car-day results from the average of several operating practices or factors. These factors vary with different railroads to produce more or fewer miles per day. By multiple correlation a few of the important variable factors for each of the 42 railroads were checked against the averages of all 42 railroads. The results per railroad ranged from 52 to 109 miles per carload-day. Only two railroads reached the 100 miles-a-day level. That test application of the work thus far on the first phase of Assignment 5 is limited, of course, to an individual railroad basis. But will serve as a starting point for the second phase.

CHAIRMAN CHRISTIANSON: Are there any questions?

B. C. DAVIDSON (Frisco): Mr. Jay, why can't the operating statistics in the ICC reports be used to determine this ratio of time in trains to total transit time?

MR. JAY: The data in those reports are obtained from the records made in conductors' wheel reports and dispatchers' train sheets. They reflect only the car movements and train movements. Few railroads, if any, assemble the data needed to calculate the time that carloads are *not* moving, or, for that matter, to determine the total transit time required to complete the haul over their railroad. The answer is that the total time data are not in the operating statistics because the railroads don't assemble them.

H. L. GASTLER (Frisco): Could the one percent waybill statistics be used to determine the average transit time?

MR. JAY: Yes, indeed. However, the waybill statistics do not now include the time that the carload starts and ends its haul. These statistics have been available for approximately 10 years, and are used extensively by traffic officials. They reflect traffic patterns and rate relationships on a national and regional basis. It has not been practical to obtain similar information for individual railroads for the reason that the data must be posted separately for each of several railroads in a sequence of interchanges.

If the waybill statistics could be used, the starting date and hour at the billing origin, such as signing the bill of lading, could be posted on the waybill; and, at the final destination post the date and hour that the carload was placed for unloading. When these waybills reach the auditing office all waybill numbers ending in "1" or "01" are reproduced and sent to the Interstate Commerce Commission. These are approximately 300,000 of these waybills received each year. The transit time information could be code-punched on cards for tabulating machines. We would then have—for the first time, too—definite, useful and fairly accurate information showing the number of hours required for a carload to complete its haul.

VICE PRESIDENT HEDLEY: Are there other questions?

Thank you, Mr. Jay.

CHAIRMAN CHRISTIANSON: I was susprised to find an editorial about this report in the current issue of "Modern Railroads. Last week I was listening to a conversation between an assistant general manager and a trainmaster. The trainmaster reached for his notebook; in it he had copied all the data from our report. I listened with satisfaction as he used that information to support his theories on train handling.

May Mr. Jay and his group have the strength, courage and wisdom to move quickly through the next phase of their study.

Committee 16 is continuing its economic analysis of locomotives, track curvature, improved freight stations, life of rail, innovations, and operations research. We hope we can report to you on all these subjects next year.

VICE PRESIDENT HEDLEY: Thank you, Mr. Christianson. Your committee has presented two very comprehensive reports, and I am sure has progressed its work toward interesting reports on its other assignments. Certainly, we are all interested in anything and everything which will improve the economics of railway operation, and we look forward at an early date to the first of the reports on your Assignment 8—Innovations in Railway Operations.

Your committee is excused with the thanks of the Association. [Applause]

[President O'Rourke resumed the chair.]

PRESIDENT O'ROURKE: We will next hear from Committee 25—Waterways and Harbors. Mr. A. L. Sams, office engineer, Illinois Central Railroad, is chairman of this committee. Will Mr. Sams and members of his committee please come to the platform? Mr. Sams.

Discussion on Waterways and Harbors

[For report, see pp. 377–380.]

[President G. M. O'Rourke presiding.]

Chairman A. L. Sams (Illinois Central): Mr. President, members and guests: This year Committee 25 is reporting on one of three assignments. That is not a good indication of our accomplishments during the past year, however, as considerable progress has been made on the other two. Subcommittee 1 is currently studying supersonic methods of making soundings and scour investigations for inclusion in the Manual. Subcommittee 2 has almost completed its report, which should be ready for publication next year.

In the absence of Mr. Li, chairman of Subcommittee 3, the report on this assignment will be presented by H. F. Kimball, assistant chief engineer, Burlington Lines.

Assignment 3—Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation, was presented by H. F. Kimball (Burlington) in the absence of Subcommittee Chairman Shu-T'ien Li, consulting engineer.

Mr. Kimball: Mr. President, members and guests: The report on Assignment 3—Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation, is submitted as information, with the recommendation that the assignment be continued.

President O'Rourke: Is there any discussion on this? If not, it will be so received. Thank you, sir.

Chairman Sams: In recent years there has been considerable activity in navigation projects. In 1954, following the approval of the St. Lawrence Seaway, the project of widening and improving the Calumet Sag Channel was revived. A committee consisting of law, traffic and engineering representatives of the interested railroads was formed to analyze the project. That committee's report was submitted to the U. S. Bureau of the Budget in Washington in opposition to the appropriation of funds for the project. I have prepared a brief summary of that report for presentation at this time.

Summary of Report Prepared by the AAR Calumet Sag Committee in Opposition to the Calumet Sag Navigation Project*

By A. L. Sams

Office Engineer, Illiinois Central Railroad

The Calumet Sag Channel is a drainage canal, 16 miles long, connecting the Little Calumet River with the Chicago Sanitary and Ship Canal. Water-borne transportation between the Mississippi River and Lake Michigan uses the Illinois Waterway, which consists of the Illinois River, Des Plaines River and the Chicago Sanitary and Ship Canal. The Cal Sag Channel is not a vital link in the Ilinois Waterway, but merely furnishes an alternate route from the Illinois Waterway to Indiana Harbor, Calumet Harbor and Lake Calumet.

For many years waterway interests and shippers in the area served by the Cal Sag have been pressing for improvements in the Channel. In 1945 the Congress approved the original project to widen the Channel to 160 ft with a usable depth of 9 ft. The cost of this work was estimated at $25,900,000. During the same session the Congress directed the Corps of Engineers to re-examine the entire project. As a result of these further studies, recommendation was made to increase the Channel width to 225 ft instead of

* This report, in full, was submitted to the United States Bureau of the Budget, September 1954.

160 ft, replace the emergency dam in the Sanitary and Ship Canal, and to extend the project to Gary, Ind., along the route of the Grand Calumet River. The revised estimate of cost of constructing the improvement was $60,000,000 as compared with the $26,000,000 previous estimate. Annual costs were estimated at $2,628,000 and predicted annual benefits were $5,194,000, which would produce a benefit-cost ratio of 1.98 to 1. On this basis, the Congress approved the project in 1946, although no funds were appropriated for construction.

The method used to determine the economic justification of the project should be examined critically. An estimate was made in 1946 of traffic that would develop within five years after completion of the project, as follows:

Coal	4,518,700 tons
Grain	800,000 tons
Petroleum	1,246,800 tons
Scrap	680,300 tons
Steel	595,000 tons
Miscellaneous	1,253,100 tons
Total	9,093,900 tons

From this total was deducted an allowance of 1,000,000 tons representing the "efficient" capacity of the present facility, leaving a potential increase in traffic of approximately 8,094,000 tons annually.

A unit saving of 57.4 cents per ton was claimed as a credit to the improvement. This saving was based on the difference between water and rail rates from origin to destination of the estimated traffic. Applying the 57.4 cents per ton to the 8,094,000 tons, produced an annual benefit of $4,646,000, to which was added $548,000 for the extension to Gary, making the total benefit $5,194,000.

Before going on to a discussion of the most recent estimates, one comment on the 1946 analysis is in order. The actual capacity of the existing Cal Sag Channel is not known. An allowance of 1,000,000 tons for the "efficient" capacity is meaningless because the term "efficient" is not defined. Certainly no tonnage should be credited to the improvement that is not in excess of that now being handled through the Channel. Assuming that all of the other quantities in the estimate are correct, the benefit-cost ratio would be less than unity when present traffic reaches 3,994,000 tons annually. In 1945 the tonnage on the Channel was 1,027,000. Traffic increased to 3,300,000 tons in 1952 and to 3,575,000 in 1953. (The 1954 traffic totalled 3,762,000 tons, indicating that the upward trend is continuing. The 1955 figure is not yet available.) It should be obvious from this performance that the benefit tonnage resulting from the project was greatly over-stated. In other words, traffic on the unimproved Channel has almost reached the point where the difference between present and predicted traffic is not enough to justify the expenditure.

The project as proposed in 1954 remains the same except that estimates of costs and benefits are increased tremendously. Construction costs are estimated at $181,000,000, or more than three times the cost in 1946 when the project was authorized. Similarly, estimated annual costs are increased to $6,790,000 and benefits to the fantastic amount of $17,646,000. The benefit-cost ratio is 2.60 to 1.

Benefit tonnage is now estimated at 8,650,000 tons annually, an increase of 6 percent over the 1946 figure. Apparently the upward trend in traffic on the present Channel was completely ignored. Estimated transportation saving is $2.04 per ton as compared with 57.4 cents in 1946. Again this represents the difference between the rail and water rates from origin to destination.

There are many practical difficulties which prevent a complete and accurate analysis of future tonnage estimates. The Corps of Engineers refused to divulge the originators and receivers of the tonnage. Therefore, it was necessary to analyze the estimates in the light of other known facts. The analysis brought out many errors of such magnitude that the benefit-cost ratio must be far below unity.

Estimated annual cost tonnage is 3,970,000. Coal traffic on the Cal Sag in recent years has averaged about 500,000 tons annually. Coal use is decreasing nationally except metallurgical coal for making steel and coal used for the generation of steam. Although metallurgical coal destined for the Chicago steel district can be transported by barge at the present time, this is not being done. Small experimental shipments have been made by barge with apparently unsatisfactory results, since the experiments have been abandoned. There is no reason to believe that the improvement of the Cal Sag would have sufficient influence to attract metallurgical coal shipments from the present pattern. Quantities of steam coal shipped will probably not increase since the recent trend is to move the plants to the coal rather than the coal to the plants. Another important new factor in the transportation of coal is the development of atomic energy. All things considered, it does not appear that the improvement project would materially increase the amount of coal handled on the Channel, and in any event, not to the extent of eight times the present tonnage.

Predicted grain tonnage 5 years after completion is 1,211,000 tons. In 1952, more grain than this amount actually moved over the present Channel. Obviously, there can be no benefits credited to the project for the movement of grain.

Petroleum products are the largest items included in the estimate of benefits. Savings of $5.14 per ton on 1,297,000 tons of gasoline and $4.48 per ton on 951,000 tons of fuel oil make a total of $11,000,000 annual benefits in the shipment of petroleum products. The $5.14 and $4.48 per ton represent the difference between the truck or rail rate and the total waterway charges for these shipments. Although consumption of these products is increasing rapidly, significant changes in the transportation of gasoline and fuel oil have occurred. The railroads now are virtually out of the business of moving petroleum and its products, since both the pipe lines and waterways can furnish lower cost transportation for these bulk commodities than can the railroads. Where rail, barge and pipe lines are in competition, the pipe lines can and do furnish the lowest cost transportation. Therefore, a comparison of rail or truck rates with barge rates produces a fictional saving. This one factor is enough to eliminate entirely the economic justification of the project.

The 1946 estimate of scrap iron and steel shipments was 680,300 tons. In 1954 this is reduced to only 86,000 tons. This figure appears to be optimistic in view of present tonnage on the Channel and the fact that scrap is seldom marketed in large quantities. Estimated future tonnages of steel and miscellaneous products are also greatly reduced in 1954, further evidence of the inaccuracy of the estimate upon which congressional approval was obtained in 1946.

The average transportation saving of $2.04 per ton also will not stand up under careful analysis. The entire saving is credited to the improvement of a 16-mile section, and no part was charged to the existing waterways, although this traffic must move over several hundred miles of waterways. Such a method of justification would not and could not be used in private industry for project justification without disastrous results.

In addition to the fact that the improvement of the Calumet Sag is not economically justified, several other important objections to the project are pointed out.

1. The increase in construction cost is so great that the Congress should be given an opportunity for re-examination of the entire project.

2. The Calumet Sag project is not an essential link in the national waterways.

3. The appropriation of funds for the project would not be in accord with the administration policy of withdrawal of the federal government from competition with private industry and of a cut in spending.

4. The Cabinet Committee and the Task Force of the Hoover Commission on Water Resources and Power are making studies of the over-all field of water resources. Appropriations of funds for the Calumet Sag should be postponed until after the recommendations of these two committees are received.

This was the case made by the railroads in opposition to the Calumet Sag project. Our arguments were without avail. Construction funds in the amount of $4,000,000 were appropriated for the first year, and the work has been commenced.

Chairman Sams: Mr. President, that concludes the report of Committee 25 at this time.

President O'Rourke: Thank you, Mr. Sams. We are glad that your committee took this opportunity to put into the Association record the salient features of the report prepared by the AAR Calumet Sag Committee in opposition to this project. As we all know, the first stages of this project have been authorized and are under way, and only the future can determine the wisdom of the action which has been taken. In view of the hundreds of millions of dollars to be expended on this project, I am sure we all hope it will bring about the benefits claimed without unfair burdens and adverse effects on the railroads.

Your committee is now excused with the thanks of the Association. [Applause]

We will now hear from our Committee 9—Highways, of which W. C. Pinschmidt, engineering assistant to vice president, construction and maintenance, Chesapeake & Ohio Railway, is chairman. Will Mr. Pinschmidt and other members of his committee please come to the platform and proceed with the presentation of their report?

Mr. Pinschmidt, I'm glad to turn the microphone over to you.

Discussion on Highways

[For report, see pp. 325–333.]

[President G. M. O'Rourke presiding.]

Chairman W. C. Pinschmidt (C. & O.): Mr. President, members and guests of the Association: Before proceeding with the presentation of our reports, Committee 9 wishes to express its sorrow at the passing of Mr. Axel Elmer Korsell at Mankato, Minn., on November 16, 1955. Mr. Korsell joined the AREA in 1920, and was a member of Committee 9 from 1927 to 1952. At the time of his retirement from active railroad service in 1949, he was engineer of grade crossings, Chicago, Rock Island & Pacific Railroad. He is survived by his widow, Mrs. Maud Payton Korsell, and four sisters.

The report of Committee 9 is found in Bulletin 525, beginning on page 325.

The committee had nine assignments. Two of them, Assignments 1 and 3, Subcommittee Chairmen C. I. Hartsell and J. E. K. Krylow, respectively, are not being reported on this year. I shall call on the other subcommittee chairmen in order, and we shall hear from them briefly.

Assignment 2, Merits and Economics of Metal Grating Type Crossings. Mr. R. E. Nottingham, division engineer, Louisville & Nashville Railroad, is chairman of the subcommittee and will present a progress report.

Assignment 2—Merits and Economics of Metal Grating Type Crossings, was presented by Subcommittee Chairman R. E. Nottingham (L & N).

Mr. Nottingham: Mr. President, members of the Association: Your committee is studying three different designs of open-grating type crossings now in use. The first of these designs includes 33 crossings installed from 1945 through 1948. No additional ones have been installed since 1948.

Crossings of this first design were expected to last 25 years. However, one was so badly deteriorated by rust after 3 years that it was replaced by bituminous paving material. The design is of light construction and not rugged enough to take the punishment of dragging equipment or corrosion resulting from brine drippings from railroad refrigerator cars, and salt used on highways in winter. This committee regards this first design as not worth further consideration.

The second design includes two crossings installed in 1949. These are reported to be in good condition at this time.

The complete crossing, including concrete headwalls, filler timbers and installation labor, is estimated to cost close to $100 per track foot in place.

Three crossings, using a third design, are under observation, installed since August 1949, costing from $53 to $78 per track foot in place. Several additional installations are under consideration.

The deck of this third design is strongly constructed. Marks on one of the decks indicate that dragging equipment had passed without damaging the panels. The deck had been treated with a rust inhibitor, and is in good condition.

Low maintenance cost, ease of removal and replacement, freedom from churning track and frost heaving due to aeration of ballast, and a rugged wearing surface, are some of the advantages which should be considered in comparing the higher initial cost of open-grating type crossings with other types of paving costing less for initial installation.

The second and third designs are giving excellent service and merit continued observation over a longer period of time.

This report is offered as information. Your committee desires to continue this assignment for further study and recommends the subject be continued. However, the committee has recommended that the assignment be reworded as follows: "Merits and economics of prefabricated types of highway–railway grade crossings."

This expanded assignment will permit a study and comparison of metal grating type paving with creosoted gum plank, concrete slab, rubber slab and other types of pavement.

Chairman Pinschmidt: Assignment 4—Outline to Guide Highway Departments and Others in Making Applications for Easements, etc. E. R. Englert, assistant engineer, Louisville & Nashville Railroad, is chairman of the subcommittee and will present the report.

Assignment 4—Outline to Guide Highway Departments and Others in Making Applications for Easements, Etc., was presented by Subcommittee Chairman E. R. Englert (L&N).

Mr. Englert: Gentlemen, last year, at the 1955 convention, we presented an outline to guide highway departments and others in making applications for highway, street and roadway easements on railroad property. This outline should give all people making such applications a pretty good idea of what we need in the way of plans and other data to process these easements. It should eliminate a lot of correspondence and extensive

field surveys, which we often have to make with our own forces after receiving an application.

We again presented this outline in Bulletin 525, and had planned at this time to move for its adoption and publication in the Manual.

Recently, however, we received a letter from Mr. Hugh Tremaine, retired district engineer, Northern Pacific Railway, who suggested that the outline should include a stipulation for an on-the-ground review by all railroad departments concerned, with the applicant, to see just what is needed. Such a review would be made before final location plans are developed, and before the formal application is submitted. It would obviously eliminate nearly all undesirable features at the very outset.

Yesterday, at a meeting of our committee, we considered Mr. Tremaine's suggestion, as well as a couple of other ideas of our own members, and after much discussion voted to postpone asking your approval of the outline for publication in the Manual until next year.

We, therefore, offer the outline that is published in Bulletin 525 as information, and ask continuation of the assignment for another year. We urge all of you to review the outline and to give us your ideas. If you will write to the chairman of our committee, or to the Association secretary, they will pass the information on to us. Thank you.

CHAIRMAN PINSCHMIDT: Assignment 5—Standard Stop Sign for Use by Crossing Watchmen, Collaborating with the Grade Crossing Protection Unit of Train Operation, Control and Signals, AAR. T. M. Vanderstempel, city traffic engineer of Pontiac, Mich., is chairman of the subcommittee, but it was necessary for Mr. Vanderstempel to leave the meeting before the committee was called to the platform, and the report will be presented by Mr. C. I. Hartsell, division engineer, Chesapeake & Ohio Railway.

Assignment 5—Standard Stop Sign for Use by Crossing Watchmen, Collaborating with the Grade Crossing Protection Unit of Train Operation, Controls and Signals, AAR, was presented by C. I. Hartsell (C. & O.) in the absence of Subcommittee Chairman T. M. Vanderstempel.

MR. HARTSELL: Mr. President, ladies and gentlemen: The AREA does not have a recommended standard stop sign for crossing watchmen, although one is contained in Bulletin 4 of the Grade Crossing Protection Unit, Train Operation, Control and Signals, Association of American Railroads.

Your committee has given serious consideration to the design of such a sign, both as to size and shape. Tests were made of larger circular disks and octagonal shape signs of several sizes, along with the present 16-in signs of TOC&S, including signs of white, yellow and red, using ordinary painted surfaces as well as those of reflex-reflective material. The size, shape, color and design of the sign as recommended by your committee are the same as those of the TOC&S sign.

Your committee recommended the adoption of the sign as referred to in the second paragraph above, using either painted or reflex-reflective material. However, due to the fact that TOC&S has withheld approval of the proposed improvement, it is necessary to change the recommendation by omitting from the drawing the words "either painted or of reflex-reflective material", and by placing a period after "white" in the third line.

Your committee recommends that the report as amended be approved for adoption and inclusion in the Manual. I so move.

[The motion was regularly seconded.]

PRESIDENT O'ROURKE: It has been moved and seconded that the sign shown on page 330, with the modification mentioned, be adopted for inclusion in the Manual. Is there any discussion?

W. H. Huffman (C&NW): Mr. President, it is no doubt quite unusual for a member of the committee to question the recommendation for adoption and inclusion in the Manual. Naturally, I am one of the minority on this particular assignment. Under Association rules, a letter ballot of all voting members of the committee, with a minimum of two-thirds affirmative vote, is required to submit a Manual proposal to the Association. This rule was complied with in this case. However, my personal convictions on this subject are so strong that I feel I would be derelict in my duty as a member of the Association if I did not place before you my side of this argument.

As indicated by Mr. Hartsell, who is subbing for the subcommittee chairman (and I might get into that a little bit later, too), the sign recommended for adoption is a round sign, a reasonable facsimile being the sign I am holding in my hand. You might ask, "What is wrong with this sign?"

My answer is that this sign is old in design and color, and is not in keeping with the times. I'm sure you will agree that the AREA is noted for its progressiveness, with personnel being on their toes. I would like to think that our Association could use the slogan or motto of General Electric, which you have all heard on your radio or seen on your TV, namely, "Progress is our most important product."

I show you now a watchman's stop sign which, in my opinion, represents a sign which is trended to our times. I want to stress principally the shape of the sign, which, as you will note, is octagonal. In highway sign parlance, an octagonal sign means only one thing—Stop—and is not used for any other purpose.

I am of the opinion that a driver's immediate reaction when seeing an octagonal sign is to decelerate, if necessary, and, in any event, to have the car under control and to be prepared to stop when reaching the sign. I do not believe this would be the immediate reaction when seeing a round sign.

Gentlemen, these are my reasons for objecting to the sign recommended by the committee for adoption and inclusion in the Manual.

You all realize, of course, that we cannot vote at this time on whether we should adopt the round or octagonal sign, but can only vote to approve or disapprove the recommendation as submitted. As you can see, I heartily disapprove of the sign as recommended, and urge—if you agree with me—that you vote "no" on this recommendation. Thank you.

President O'Rourke: Thank you, Mr. Huffman.

Mr. Hartsell: In the committee discussion of this subject, considerable reference was made to the adoption of the standard stop sign, the octagonal sign, colored red and white, such as I hold in my left hand. I think you will agree that there is no question but that it gives you the impression, "stop," but it also gives you one other impression, and that is this: once you have stopped, you may proceed after that stop.

The circular sign, such as shown in the Bulletin, is a distinctive sign which means one thing—"stop and stay stopped." It is used in no spot other than at a highway–railway grade crossing. The 66⅔ percent of the committee which voted to retain the circular disc had that thought in mind.

Mr. Huffman: I don't agree with Mr. Hartsell, as you all know by now. [Laughter] I don't agree that a stop sign means "stop and proceed." I don't thing anybody is silly enough to just stop and proceed. After they stop, they look to see whether the highway they are going to cross is free from anything that might be in their way. That's all I've got to say on that.

Chairman Pinschmidt: Mr. President, I know that there is an honest difference of opinion here. Mr. Huffman has expressed himself. He served notice on us that he was

going to do this when he sent in his ballot. His was the lone dissenting vote, and the committee has thoroughly covered the situation to its satisfaction—that is, over two-thirds of us have.

The sign as submitted has been approved by the Grade Crossing Protection Unit of Train Operation, Control and Signals, and unless there is some unexpected change, it will appear in new Bulletin 5 of that committee.

We had in mind that we could improve on that sign, and offered our sign with the provision for the use of reflex reflecting material, but we were voted down by the Grade Crossing Protection Unit, so, rather than not have any sign, we thought we'd better go along with them and have this sign, which seems to have general approval.

PRESIDENT O'ROURKE: Thank you, sir.

Is there any discussion from the floor?

MR. HUFFMAN: I don't question the chairman's statement that I was the only dissenting voter. However, we had a meeting yesterday morning, and we were talking about certain changes in this recommendation which didn't actually have anything to do with my remarks on the type of sign that should be used, but rather, on these changes that were mentioned by Mr. Hartsell just a few minutes ago.

I would like to bring out the fact that another unusual circumstance developed. Mr. Vanderstempel, a very well qualified individual, was not given the opportunity to present this report, and the reason was that he agrees with me [Laughter]. Maybe there was only one dissenting vote at the time the proposal was sent out for letter ballot, but I'm sure that is not the case at the moment.

CHAIRMAN PINSCHMIDT: Mr. President, I dislike to prolong this discussion, but I must say that Mr. Vanderstempel was not prevented from submitting his report. He came to me about four-thirty and said, "I'm supposed to catch a plane out of here, to be in Lansing. If this report is going to be delayed, I'll not be able to present it. Will you please have someone handle it for me?" [Laughter]

PRESIDENT O'ROURKE: Anything else, Mr. Huffman?

MR. HUFFMAN: There is something very strange about this because Mr. Vanderstempel is still here.

R. E. DOVE (Railway Track & Structures): I'm inclined to go along with the octagonal sign. When you take your driver's test, you understand that the octagonal sign is a stop sign. I think the committee ought to go still further and give it a yellow back ground. Why didn't they do that?

MR. HARTSELL: The TOC&S committee of the AAR agreed with us that we wish the distinctive sign, rather than the octagonal sign, for the reasons I have already stated—for a stop-and-stay indication rather than a step-and-proceed indication. As to the color, we were overruled by TOC&S.

Actually, Committee 9 agreed with you that a reflex-reflective material should be permitted, but in order to gain some ground, even though we don't gain all we desire, we have recommended—and I have personally moved—the adoption of the circular sign.

You will kindly note that we have not specified the type of material that will go on the sign. We leave that up to your good judgment. We feel that each railroad is competent within itself to decide whether it will be reflex-reflective material, paint, or, in case they desire, reflective buttons. So, if you prefer the yellow, that's your privilege.

PRESIDENT O'ROURKE: Thank you, sir.

Is there further discussion from the floor? There is a motion before the house for the adoption—for inclusion in the Manual—of the sign proposed by the committee, as shown in Fig. 9 on page 330 of Bulletin 525.

CHAIRMAN PINSCHMIDT: With the deletion of the note, Mr. President.

PRESIDENT O'ROURKE: With the deletion of the note at the bottom, "either painted or of reflex-reflective material." Is that it?

CHAIRMAN PINSCHMIDT: That's right.

PRESIDENT O'ROURKE: I believe everybody understands the motion now before the Association. All in favor, say "aye." Contrary, "no." That's about as evenly stated as sound can carry up here. It appears that we're going to need a count of hands. I am going to appoint Mr. Dove to count the hands.

Those in favor of the motion, please raise their hands.

MR. DOVE: Forty-one for.

PRESIDENT O'ROURKE: Those opposed, please raise your hands.

MR. DOVE: Fifty-three against.

PRESIDENT O'ROURKE: The motion was lost by a vote of 53 to 41. [Applause]

Mr. Pinschmidt, the Chair is somewhat at a loss as to just what is to be done now respecting your Assignment 5—Standard Stop Sign. It seems to me we've left it hanging in the air. Are you going to give it reconsideration?

CHAIRMAN PINSCHMIDT: Yes, Mr. President. I'm glad you raised that question because I hesitated to do so. Frankly, I was going to rise to a point of order as to the eligibility of some of those voting. I don't know whether all were qualified voters.

PRESIDENT O'ROURKE: Do I understand that you are challenging the vote of those members on the floor, or do you question that some of them may not be members, or just what is the question in your mind?

CHAIRMAN PINSCHMIDT: They may not have the right to vote.

PRESIDENT O'ROURKE: Now you've raised a point of law that makes it quite difficult for me. [Laughter]

We might have a show of hands of those people out there who are not members and are not eligible to vote. Is that what you had in mind?

CHAIRMAN PINSCHMIDT: No, of those who are eligible to vote, Mr. President.

V. R. WALLING (C&WI) Retired): Mr. President, I would like to ask a question concerning what he may have in mind. Members Emeritus of committees do not have the right to vote in committee, but they are still members of the Association, and have the right to vote as members of the Association.

PRESIDENT O'ROURKE: Are there any men in the audience who voted on this proposition who are not qualified to vote? If there are, I'd like to have them raise their hands.

QUESTION: Mr. President, does a Junior Member have a vote?

PRESIDENT O'ROURKE: No. A Junior Member does not.

QUESTION: I voted on it. [Laughter]

PRESIDENT O'ROURKE: Which way did you vote? [Laughter]

The majority still stands—52 to 41.

No one else admits his ineligibility Mr. Pinschmidt, so shall we proceed now?

CHAIRMAN PINSCHMIDT: Yes, sir. I presume that the committee must take up where it started and go over this entire subject again. Oddly enough, the gentleman who proposed the assignment, and who wanted to have a sign, was the one who has killed it. [Laughter]

MR. HUFFMAN: I didn't want that sign. [Laughter]

CHAIRMAN PINSCHMIDT: Assignment 6—Problems Related to Location and Construction of Limited Access Highways in Vicinity of or Crossing Railways. S. B. Gill, grade crossing engineer, Erie Railroad, is chairman of the subcommittee, and will present the report.

Assignment 6—Problems Related to Location and Construction of Limited Access Highways in Vicinity of or Crossing Railways, was presented by Subcommittee Chairman S. B. Gill (Erie).

Mr. Gill: Mr. President, gentlemen of the Association: The scope of this report is confined to limited access highways, which are highways that may be defined generally as highways especially designed for through traffic and to which abutting property owners have no right of access, except at specified locations.

Legislative proposals before the Congress, together with present planning by many State Highway Departments, assure us that we will be faced with numerous highways of this type in the immediate future. This makes imperative that the railways should be well informed relative to the problems likely to be encountered.

It is the opinion of this committee that prompt action on the part of the interested railway in the early stage of the planning for limited access highways may result in a more favorable location of these roadways.

This report is submitted as information, with the recommendation that the subject be continued. Your committee will welcome any comments from the Association that will further its study of this assignment.

President O'Rourke: The report will be so received.

Chairman Pinschmidt: Assignment 7—Sight Distance at Highway–Railway Grade Crossings. J. M. Trissal, assistant chief engineer, Illinois Central Railroad, is chairman of the subcommittee. While there is no written report on this subject, the committee felt that a brief comment by the chairman of the subcommittee would be appropriate. Mr. Trissal will comment on the report as submitted last year and printed as information in Bulletin 518.

Assignment 7—Sight Distance at Highway–Railway Grade Crossings, was presented by Subcommittee Chairman J. M. Trissal (Illinois Central).

Mr. Trissal: Mr. Chairman, gentlemen: Your committee presented a report at the 1954 annual meeting which was contained in Bulletin 518, and on pages 380 and 381 of the Proceedings of the 54th annual convention of the Association.

In presenting this report your committee realized that there were many debatable points involved in making any specific recommendations on such a complicated subject. It was for this reason that comments were solicited from the membership. To date no comments have been received. The committee feels that the diagram and formula presented in 1954 were so largely dependent upon the reaction of the driver of the automotive vehicle that it is dangerous to make any specific recommendations. For example, if a driver proceeding at maximum allowable speed is closer to the railroad track than the point where it is first possible for him to see the train, and then sees the train and attempts to stop short of the crossing, there is a grave possibility that he will be hit by the train if we are to assume that his brakes operate in the average manner. The safe procedure is to proceed over the crossing at the maximum allowable speed. This, however, is contrary to the normal driver reaction.

It is for this reason that your committee is making no further recommendations or report at this time. However, we again wish to solicit your comments on the 1954 report.

Chairman Pinschmidt: Assignment 8—Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railway. At the request of the committee, this assignment was added

during the year. Mr. D. W. Hughes, signal engineer, Railroad Safety Inspector, Michigan Public Service Commission, is chairman of the subcommittee, and will present the report.

Assignment 8—Recommended Protection at Highway–Railway Grade Crossings Where One-Way Traffic on the Highway Crosses One or More Tracks on the Railway, was presented by Subcommittee Chairman D. W. Hughes [Michigan Public Service Commission].

MR. HUGHES: Mr. President, gentlemen: Assignment 8 grew out of a rapidly spreading practice on the part of roadway authorities to create one-way streets, roads and divided routes with varying widths of median strip.

A search for printed material, diagrams or other data pertinent to the subject of crossing protection at such locations brought forth little or nothing by way of past experience or indicated standard practice.

It was felt that Committee 9 should study the matter and that the Association's Manual should provide guidance in order that uniform good practice be observed.

Our subcommittee has been in existence long enough to offer an initial progress report as information. It shows that the subject is somewhat controversial, populated with so-called "straw men", and while innocent appearing on the surface, has produced rather lively discussion.

There is a semblance of concurrence on a few of the phases to be considered, namely, the stability of roadway plans concerning the reinstituting of two-way traffic either as an emergency or a planned detour route, the economic justification of locating signals on the non-traffic approach side of the crossing, or even focusing lamp units toward that direction.

These and several allied considerations are being explored toward the end that a plan or procedure will result, bearing wide enough acceptance by the members as to confer the stamp of good practice. The committee solicits your comments, questions and suggestions, and it is recommended that the subject be continued.

PRESIDENT O'ROURKE: Your recommendation will be so received.

CHAIRMAN PINSCHMIDT: Assignment 10—The Effect of Highway Improvement Projects on Railway Properties, Collaborating with the AAR Committee on Grade Crossing Elimination. Mr. J. T. Hoelzer, engineer maintenance of way, Baltimore & Ohio Railroad, is chairman of the subcommittee, and will present the report.

Assignment 10—The Effect of Highway Improvement Projects on Railway Properties, Collaborating with the AAR Committee on Grade Crossing Elimination, was presented by Subcommittee Chairman J. T. Hoelzer (B&O).

MR. HOELZER: Mr. President, gentlemen: The report on Assignment 10 was prepared in collaboration with the AAR Committee on Grade Crossing Elimination. It is presented as information, with a view to recommending its adoption next year for inclusion in the Manual.

Your comments or criticisms are invited.

CHAIRMAN PINSCHMIDT: Mr. President, this concludes the presentation of subcommittee reports. However, we have another part of our program. I am not able at this time to present to you, in person, the speaker indicated on your printed program. Mr. Hal Hale had planned for some time to be with us. It was only a few days ago that he was obliged to cancel his engagement because of pressing legislative matters in Washington, where it is necessary for him to be present today.

We prevailed on Mr. Hale, however, to give us the benefit of his thinking by furnishing a brief statement highlighting the matters he had intended to discuss. I have such a statement, which should be of the utmost interest to railway officers. It is brief and to the point. I should like to read it to you.

Statement Respecting Proposed Highway Legislation

By H. H. Hale
Assistant to Vice President, Highway Transportation, AAR

In the first session of the 84th Congress, consideration was given to an expanded highway program summarized in a report by a special committee named by President Eisenhower and under the chairmanship of General Lucius D. Clay. The recommendations of the Clay committee were unfavorably received in both houses of the Congress. In this instance the Senate, acting through its Roads committee under the chairmanship of Herbert Gore of Tennessee, enacted a bill sponsored by Senator Gore prior to any action being taken in the House. The Gore Bill, S–1048, was quite different from the recommendations of the President's committee and, briefly, would authorize a 5-year highway program averaging annually $2,532,000,000, present federal highway aid authorization averages $966,000,000.

Senator Gore's bill was basically patterned after existing federal-aid legislation, with greatly increased amounts to be authorized for the federal-aid systems. As is generally known, after many weeks of deliberation, the House first voted to kill the Administration recommendations and subsequently voted to kill the substitute Fallon bill, H. R. 7474, so that the Congress adjourned without enacting any new federal aid legislation. The main points of controversy dealt with the financing of the program, and it was this financing problem to which the trucking industry took strong exception because, for the first time, it would have set up a federal highway user charge with differentials levied against the heavy truck. In view of the fact that this controversy played such an important part in consideration as to the measure, steps were initiated shortly after the Congress adjourned by Chairman Fallon of the House committee to bring to the Congress through the Bureau of Public Roads and the Commerce Department a factual analysis of the highway user charge and the differential question.

When the second session of the 84th Congress convened in January, there was still before the committee of the House S. 1048 as passed by the Senate. Shortly after reconvening, the House committee initiated new hearings on highway matters, but these have been conducted in executive session. A question of financing the program was referred to the Committee on Ways and Means, which committee held extensive hearings on the subject. The Association of American Railroads submitted testimony expressing its viewpoints on the sound financing program. A new element of considerable importance came into the picture in that the American Automobile Association for the first time took an aggressive position, reversed their previous policy position, and announced a financing program of their own, recognizing the controversial differential problem.

Shortly before the Ways and Means Committee opened its hearings Congressman Boggs (Democrat of Louisiana) introduced an "across the board" financing bill. This bill, H. R. 9075, would have increased federal taxes on gasoline, diesel and special motor fuels, tires, retread material, and the excise or ad valorem tax on trucks, buses and trailers, but with the exception of the latter all were across the board or applied equally against

the automobile and the heavy vehicle. In the case of the last named excise tax, heretofore automobile owners had paid a federal tax of 10 percent on the purchase of new vehicles, whereas the trucking industry paid only an 8 percent tax.

After highly controversial hearings, the Ways and Means committee agreed upon a tax program along the lines of the Boggs measure, but with the additional provision that there should be a special tax on heavy vehicles in excess of 26,000 lb, at the rate of $1.50 per thousand pounds. While this is only a token insofar as equitable highway user charges are concerned, it is a step in the right direction and would establish a differential principle. The Ways and Means committee has not yet made its formal report, but is expected to do so this week.

During the past week the House Subcommittee on Roads has been attempting to agree on the authorization measure. It has not thus far done so. It, too, is expected to conclude its deliberations this week.

There are two essential points which the railroad industry has been advocating. Number 1 is the incorporation in any legislation of a fair and equitable user charge to finance the program on a pay as you go basis. Number 2 is the inclusion in new legislation of a federal ceiling on the sizes and weights of vehicles. Obviously, both of these points have been violently challenged by the trucking industry. At this time it is not possible to say what form the final authorization measure may take, but it appears that it will provide for a greatly expanded highway program approximating $37 billion in federal aid with matching funds from the states to bring the total in excess of $50 billion. It is anticipated that this amount would be expended over a 13-year period. The new bill will probably include radical deviations from previous federal-aid legislation, particularly with reference to reimbursement to states that have built toll roads, reimbursement of utilities, Bacon–Davis labor provisions, and several others, all of a highly controversial nature. Assuming that parliamentary procedures are worked out, it is probable that the tax measure will be incorporated in the final draft of the authorization bill in order to bring the complete measure before the House.

It is quite probable that the financing section will be brought to the floor under a closed rule as it was last year. This means that it will not be subject to amendment on the floor and will have to be accepted or rejected in one package. Assuming passage in the House, the measure will then go to the Senate where it will ultimately have to be agreed upon in conference committee between the two houses. Because the measure contains taxing provisions, it will undoubtedly have to be referred to the Senate Committee on Finance under the chairmanship of Senator Byrd of Virginia where public hearings will be held.

The trucking industry, through the trucking spokesman, American Trucking Association, has announced that it does not intend to continue fighting against the tax provisions in the House, but will direct its efforts toward obtaining such adjustments in the Senate. The adjustments above referred to mean the elimination of any differential against the heavy vehicle. It is not possible at this time to predict the Senate reaction. The trucking industry has levelled considerable fire at the incorporation of a federal ceiling on sizes and weights. This section was in the Gore bill passed last year by the Senate, was in the House bill voted down finally by the House, and is incorporated in the present Fallon bill before the House. The provision would say, briefly, that no state can receive federal-aid funds for the interstate system in that state if it exceeds present statutory load limitations in effect in the state, or those of the American Association of State Highway Officials standards, whichever are the greater. This provision would not deprive any state

of privileges it now legally enjoys, nor would it prevent any state from increasing its standards if they remain below American Association of State Highways Official standards. For example, 33 states now have a single axle load limitation of 18,000 lb, 15 states and the District of Columbia exceed those statutes, with the highest presently being 22,400 lb on a single axle. These latter states could not, under the proposed section, go any higher than they now are, nor could any of the 33 states go higher than the 18,000 lb, which is the AASHO standard.

As an example of activity now under way in the Congress, a move has been made in the Public Works committee to write a federal ceiling of 24,000 lb on a single axle. Should such a thing be done, it would mean that immediately there would be moves made in the state legislatures to increasing existing statutes to the federal ceiling of 24,000 lb. The effect of such action can be understood immediately, however, it is not possible to say that the move may not be successful.

As mentioned previously, the railroad industry's position as expressed through the AAR has been neither for or against a highway program, but to support necessary legislation in any program adopted providing for pay as you go financing, with fair and equitable user charges recognizing the differential principle and with a federal ceiling on sizes and weights as included in the Gore bill passed by the Senate in the last session, and as presently written in Section 7E of the Fallon bill.

Chairman Pinschmidt: Mr. President, this concludes the report of Committee 9, and also concludes my term as chairman of the committee. I wish to thank all of the members who have helped to carry on the work so well during my term of office.

I should like to present our new vice chairman, Mr. J. M. Trissal, assistant chief engineer, Illinois Central Railroad.

Succeeding me as chairman is Mr. C. I. Hartsell, division engineer, Chesapeake & Ohio Railway, who has been a member of the committee since 1947, and has served as vice chairman for the past three years. At the conclusion of this annual meeting he will be the new chairman of Committee 9—Highways. [Applause]

President O'Rourke: Thank you, Mr. Pinschmidt. Your committee carries forward a most important phase of our Association work, and we look to it to keep us fully informed with respect to all phases of the parallel or conflicting interests of highway and rail transportation. Perhaps we'd better not mention anything about the conflicting interests within the committee. [Laughter] That is a facetious remark which need not be put in the record.

Mr. Pinschmidt, I would like to take this opportunity to congratulate and thank you for your able leadership of Committee 9 during the past three years.

To carry on where you leave off, we are happy to welcome as your new chairman, Mr. C. I. Hartsell, and as your new vice chairman, Mr. J. M. Trissal. We are sure these two men will ably progress the splendid work done under your leadership for the last three years.

Tellers Committee

Before excusing your committee, I should like to announce that R. A. Bardwell, engineer of tests, Chicago & Eastern Illinois Railway, Danville, Ill., has been appointed by your President as chairman of the Tellers Committee to canvass the ballots cast for the officers of the Association for the ensuing year.

The Executive Secretary has been instructed to turn over the ballots to the tellers. They will be counted in Private Dining Room 9 tomorrow morning, beginning at 9 am,

and the names of the successful candidates will be announced at the Annual Luncheon tomorrow noon.

I think you may be interested in the registration, up to this afternoon. In 1955, an exhibit year, we had 999 members and 750 guests, for a total registration of 1749. This year, a non-exhibit year, we have 963 members and 740 guests, for a total of 1703, a difference of 46 members, which I think is very remarkable. This compares with a total of 1543 in 1954 and of 1439 in 1953.

I think I should express to you the appreciation of the officers and the Board of Directors of the Association for such a wonderful turnout.

Mr. Pinschmidt, your committee is now excused with the thanks of the Association, and the meeting will stand recessed, to reconvene tomorrow morning at 9 am in the Red Lacquer Room.

[The meeting recessed at 5:40 o'clock.]

Morning Session—March 14, 1956

[The meeting reconvened at 9 o'clock, President O'Rourke presiding.]

PRESIDENT O'ROURKE: The meeting will please come to order. It is necessary that we start promptly, because we have a long and interesting program this morning, with several special features, and I am hopeful that we can expedite it at much as possible in order that we might adjourn promptly at twelve noon for our Annual Luncheon. On the other hand, in connection with all committee reports, I invite your comments and criticism, to the extent that time will permit, and ask that when addressing the Chair from the floor, you use the microphones and state your name and railroad.

Our first committee report is that of our Committee 13—Water, Oil and Sanitation Services, the chairman of which is Mr. H. L. McMullin, engineer of tests and water supply, Texas & Pacific Railway, Dallas, Tex. Will Mr. McMullin and members of his committee please come to the speaker's table? And may I ask that he, the vice chairman and secretary, and all reporting subcommittee chairmen, take seats as close as possible to the podium, in order to minimize "in transit time" to the podium during the presentation?

Discussion on Water, Oil and Sanitation Services

[For report, see pp. 335–346.]

[President G. M. O'Rourke presiding.]

CHAIRMAN H. L. MCMULLIN (Texas & Pacific): Mr. President, members of the Association, guests and friends: The report of Committee 13 will be found in Bulletin 525, on page 335. Our first report will be on Assignment 3—Federal and State Regulations Pertaining to Railway Sanitation, Collaborating with Joint Committee on Railway Sanitation, AAR: Mr. H. W. Van Hovenberg, engineer of tests and sanitation, St. Louis–Southwestern Railway, is the chairman of this subcommittee, and he will give you the report.

Assignment 3—Federal and State Regulations Pertaining to Railway Sanitation, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by Subcommittee Chairman H. W. Van Hovenberg (St. Louis–Southwestern).

[Mr. Van Hovenberg then read the published report on this assignment in full.]

Chairman McMullin: Assignment 4 will be handled by W. F. Arksey, engineer of water service and fuel facilities, Great Northern Railway, who is subcommittee chairman.

Assignment 4—Cathodic Protection of Pipelines and Steel Storage Tanks, Collaborating with the Electrical Section, AAR, was presented by Subcommittee Chairman W. F. Arksey (Great Northern).

Mr. Arksey: Mr. President, members and guests: Dieselization has increased the use of buried steel pipe and steel tanks on railroads with their attendant corrosion problems. This new assignment was made to develop practical protection methods. Cathodic protection is the application of an electric current to a structure to reverse the current that normally flows from the metal to the soil, causing corrosion.

We propose to develop a report that will allow a railroad to handle the majority of cathodic protection systems required on their lines. Large systems should be designed by competent corrosion engineers because of the possibility of complications arising from unusual conditions.

This report is offered as information.

President O'Rourke: It will be so received.

Chairman McMullin: Assignment 5 was handled by a subcommittee of which Mr. M. A. Hanson, engineer of research of the Gulf, Mobile & Ohio Railroad, was chairman. Mr. Hanson was unavoidably detained, and cannot be here to present his report. It will be presented therefore, by one of his subcommittee members, Mr. E. L. E. Zahm, water engineer of the Missouri–Kansas–Texas Lines, of Parsons, Kan.

Assignment 5—New Developments in Water Conditioning for Diesel Locomotive Cooling Systems, Collaborating with Mechanical Division, AAR, was presented by E. L. E. Zahm (Katy) in the absence of the Subcommittee Chairman M. A. Hanson (GM&O).

Mr. Zahm: Mr. President, members and guests: Laboratory tests were conducted using sodium molybdate as a corrosion inhibitor. The pH of the test solutions was held between 8.5 and 9.5. The concentration was varied from 100 ppm to 2000 ppm.

The tests indicated alkaline sodium molybdate was an effective corrosion inhibitor for all metals commonly found in diesel cooling systems except cast iron. Its failure to inhibit cast iron against corrosion precludes its use in a diesel cooling system.

Several railroads tested two different soluble oils as corrosion inhibitors. Both oils gave a considerable degree of protection for the relatively short duration of the tests. The tests were discontinued for several reasons. The emulsions were not stable, radiator hose trouble was widespread, and the oil coating on the radiators were believed to reduce heat transmission. One railroad experienced severe sludging in the cooling systems.

These tests do not give much encouragement that either of the types of compounds tested could be substituted satisfactorily for the presently used inhibitors.

This report is presented as information.

President O'Rourke: It will be so received.

Chairman McMullin: Assignment 6 was handled by a subcommittee of which Mr. T. A. Tennyson, Jr., chief chemist of the St. Louis Southwestern Railroad was chairman. Mr. Tennyson was also unavoidably detained, and another member of that subcommittee will present the report—Mr. M. R. Bost, assistant engineer of the Milwaukee Railroad.

Assignment 6—Railway Waste Disposal, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by M. R. Bost (Milwaukee Road) in the absence of Subcommittee Chairman T. A. Tennyson, Jr. (St. Louis–Southwestern).

Mr. Bost: Mr. President, members of the Association and guests: Your committee has found that in the operation of facilities for separating oil from waste waters when emulsified oil is present, the simple mechanical action on the gravity-type oil trap must be supplemented by chemical methods which remove the oil by sedimentation or break the emulsion so that the oil can rise to the surface of the water and be skimmed off. Chemical methods which remove the oil by sedimentation involve the use of coagulants widely known in water treatment and the control of the pH of the water. Emulsions may be broken by neutralization of the stabilizing agent and by the use of proprietary emulsion-breaking compounds. But there is no universal method of chemical treatment of water for breaking emulsions, so the procedure and design of plants must be selective. Laboratory control is essential to the satisfactory operation of the chemical methods of separating oil from water. This report is presented as information.

President O'Rourke: It will be so received.

Chairman McMullin: Assignment 7 was handled by a subcommittee headed by Mr. L. E. Talbot, chief chemist of the Texas & Pacific Railroad, who will now present the report.

Assignment 7—Treatment of Water for Cooling Purposes, was presented by Subcommittee Chairman L. E. Talbot (Texas & Pacific).

Mr. Talbot: Mr. President, members of the Association and guests: This is the second and final part of this report, and is submitted as information:

The increased use of air conditioning, both in railroad rolling equipment and office buildings, and the increased use of internal combustion engines on railroads during the past few years have introduced new problems in water treatment. Last year your committee presented as information (Proceedings, Vol. 56, 1955, pages 347 to 355 incl.) the various types of cooling systems involved, together with the types of scale and formations found in these systems. The report also outlined some of the current methods used to prevent these formations. This part of the report outlines some of the problems encountered due to algae and slime present in the cooling system, and due to the gradual wood deterioration of the cooling tower. This report also includes the current methods for the solution of the above problems.

The three main groups of organisms which may give trouble in recirculating systems are the algae group, the bacteria group, and the fungi group. In order to prevent the formation of the organisms, it is necessary to analyze the supply water, the cooling water, and the organisms present to determine which type of treatment would be most effective. Some of the chemicals used to prevent these formations are chlorine, bromine, copper sulfate, copper citrate, sodium pentachlorophenate, and the quarternary ammonium compounds. All of the above chemicals have certain disadvantages. For instance, chlorine is lost through aeration; bromine is costly and hazardous; copper precipitates at a pH of 8.5 and over; sodium pentachlorphenate is toxic to fish and animals; and high salt concentrations reduce the effectiveness of the ammonium compounds. Test results show that slime and algae can best be controlled by using a combination of two or more of the above chemicals. Again, it should be emphasized that a complete analysis should be made before deciding which combination should be used.

Chemical deterioration of the cooling tower wood, known as delignification, involves the removal of the lignin binder from the cellulose fibers. In the case of delignification, sodium carbonate is the known offender. In order to prevent this it is necessary to maintain the pH of the water between 7.0 and 7.5 by the use of an acid.

Biological destruction of the cooling tower is caused by microorganisms which utilize the wood for food. As a preventative measure it would appear that the use of algicides that will be absorbed by the wood, such as the copper and chlorophenate materials, would prove most effective.

CHAIRMAN MCMULLIN: Assignment 8; D. C. Teal, superintendent of water supply of the Chesapeake & Ohio Railroad, is subcommittee chairman of this group, and he will present the report.

Assignment 8—Diesel Oil and Water Servicing Facilities, Collaborating with Mechanical Division, AAR, was presented by Subcommittee Chairman D. C. Teal (C. & O.).

MR. TEAL: Mr. President, members of the Association and guests: The railroads have been more or less dieselized for a number of years, and considerable study has been given to the design, construction and operation of diesel fueling and watering facilities. Several years ago it was felt that research and experimental phases had progressed to the point where recommended practices should be considered. As a result, the subject was assigned to this committee, and, following careful study, a report, embracing recommended practices, was made to the Association at its 1955 annual meeting. This was published in Bulletin 518, and later in Vol. 56, 1955, of the Proceedings, pages 355–368, incl., with the understanding that the assignment would be continued for another year in order to collaborate further with other interested organizations and otherwise to give further consideration to the material submitted.

Your committee has accordingly carefully reviewed last year's report, and with minor revisions, now submits the material, as revised, with recommendation that it be adopted and published in the Manual. This recommendation has the approval of collaborating organizations.

In accordance with the Association rule that proposed Manual material should not be reprinted in reports if it has appeared in substantially identical form not more than one year before being submitted for adoption, the proposed material is not reprinted herein. However, it is necessary to call your attention to the revisions made to last year's report, made largely upon the recommendations of the collaborating organizations.

The next to last sentence at bottom of page 359 has been changed to read: "At main line stations where fast fueling of multiple units is required, the pumping equipment should be designed to provide a 200 to 300 gpm rate of flow simultaneously to each diesel unit."

The material at top of page 362 appearing under E. Unloading Facilities, has been revised and rearranged to emphasize the advantages of overhead or dome unloading, especially from a fire protection viewpoint.

The second sentence under "Paving of Fueling Areas", appearing on page 364, has been replaced by one which reads: "Removal of ice and snow by hand, which can become an expensive maintenance problem, has in several cases been eliminated by the installation of radiant heating coils in the concrete."

The first two paragraphs devoted to electrical work appearing on page 364 have been changed to read:

"Electrical Installations: Should conform to governing state and local codes or, in the absence of such codes, to the latest revision of the National Electric Code. Fuel oil pump houses would be considered a hazardous location under this code and would require explosion-proof equipment. All electrical work should be made vapor proof, and motors should be totally enclosed and have a sealed terminal box. The wiring should be appropriate to the degree of hazard. Circuit breakers and starters should be in dust-tight, vapor-proof cases. In this connection, many railroads install switches and starters in a panel box outside the pump house."

The sentence devoted to "Portable Equipment", appearing at the extreme bottom of page 364, has been changed to read:

"Portable Equipment: Hand fire extinguishers of appropriate size should be located both inside and outside pump houses and also convenient to unloading points and fueling areas. There should be at least two such extinguishers at the fueling area, so placed as to minimize the likelihood of both being surrounded by fire at the same time. Dry powder extinguishers are recommended for this service. The ones located outside should be fully protected against the weather, housed in cabinets, painted red and otherwise identified."

Mr. President, I move that the material on diesel oil and water servicing facilities, first published in Bulletin 518 and subsequently in the Proceedings, Vol. 56, pages 355 to 368, incl., later revised in accordance with changes noted in Bulletin 527, pages 342 and 343, be adopted and published in the Manual, and that this material be designated as Part 9, under a general heading "Diesel Locomotive Fuel and Water Services".

[The motion was regularly seconded.]

President O'Rourke: It has been moved and seconded, gentlemen, that the material on diesel oil and water servicing facilities, as revised, be adopted and published in the Manual. Is there any discussion?

G. W. Miller (Canadian Pacific): I note the recommendation that the pumping equipment be designed to provide 200 to 300 gpm rate of flow, simultaneously, to each diesel unit. It is my understanding that the nozzle which is used to deliver the fuel oil to the locomotive usually restricts the flow to somewhat less than 150 gpm. If we endeavor to deliver as much as 200 to 300 gpm of oil into a diesel fuel oil tank, there is a possibility of blowing up the tank, because the exhaust air ports above the fuel oil tank are not large enough to let the air out at that rate.

Could you explain whether that has been investigated, Mr. Teal?

Mr. Teal: Mr. Miller, I'll start my explanation by stating that the material presented is largely the result of a questionnaire sent out to some 40 large railroads. The material represents majority opinion and majority practices in most cases. We have found that most railroads use a 2½-in discharge hose, and many railroads no longer use the nozzle itself. The hose nozzle valve, which is trigger-operated, has been discarded in many cases; they use either a 2½ or 3-in hose, just a plain hose, which connects on to the side of the diesel.The problem of getting 200 or 250 gpm is apparently not a problem on many railroads.

I might also add that we changed our recommended practice at the insistence of several railroads that wanted that large delivery specified, particularly on main lines at through points, where they must get their diesels away fast. They want the at 200 to 300 gal delivery rate.

President O'Rourke: Is there any other discussion? Are we ready for the question?

[The motion was put to a vote, and carried.]

President O'Rouke: Your proposition is carried, Mr. Teal. Thank you, sir.

CHAIRMAN MCMULLIN: Assignment 10—we have a brief statement of progress, which will be presented by the Subcommittee Chairman, Mr. J. M. Bates, general fire and sanitary engineer of the Union Pacific Railroad, at Omaha.

Assignment 10—Detection and Disposal of Radioactive Materials in Air, Oil and Water Filters on Diesel Locomotives and Other Equipment, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by Subcommittee Chairman J. M. Bates (Union Pacific).

MR. BATES: Mr. President, members of the Association, and guests: During the time of the tests conducted by the Atomic Energy Commission, from February to June 1955, incl., several atomic bombs were exploded on Yucca Flats in the vicinity of Las Vegas, Nev.

Concurrent with these tests, the office in charge of the off-site activities ran numerous tests in connection with the fall-out materials and radioactivity associated with these various atomic tests on the Union Pacific Railroad right-of-way between Las Vegas, Nev., and Salt Lake City, Utah. The Atomic Energy Commission tests indicate that most of their readings were negative in nature relative to the current standards and do not exceed their standards for the 1955 atomic tests relative to radioactivity along the right-of-way, exposed railroad cars, locomotives, buildings, etc.

We are also advised by James G. Terrill, Jr., chief radiological health program, Division of Sanitary Engineering Services, of the Department of Health, Education and Welfare, that no serious exposures were observed relative to contamination of rolling equipment, oil, water and air at the time the bombs were being detonated along the railroad right-of-way.

This report is submitted as information.

PRESIDENT O'ROURKE: Thank you, sir. It will be so received.

CHAIRMAN MCMULLIN: Assignment 12: we have a final report presented for adoption and publication in the Manual. This assignment was handled by T. L. Hendrix, Jr., sanitary engineer of the Chesapeake & Ohio Railroad, but Mr. Hendrix could not be here to present his report. Mr. R. C. Bardwell, engineer of tests of the Chicago & Eastern Illinois, will present the report.

Assignment 12—Sterilization of New and Repaired Water Wells, Pipelines and Other Equipment Used in Handling Drinking Water, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by R. C. Bardwell (C&EI) in the absence of Subcommittee Chairman T. L. Hendrix, Jr. (C&O).

MR. BARDWELL: Mr. President and gentlemen: This report constitutes a consolidation of current procedures in water main and well sterilization used by member railroads, together with recommendations of various state health agencies and the American Water Works Association. It has been prepared by your committee to represent recommended practice.

Mr. President: I move that this material be adopted and published in the Manual under Part 8—Sanitation.

[The motion was regularly seconded.]

PRESIDENT O'ROURKE: You have heard the motion. Is there any discussion? If not, are we ready for the question?

[The motion was put to a vote, and carried.]

PRESIDENT O'ROURKE: It is so ordered. Thank you, sir.

CHAIRMAN MCMULLIN: Mr. President, that concludes our report.

PRESIDENT O'ROURKE: Mr. McMullin, your committee has presented interesting reports on eight of its assignments, including the presentation of two important documents for inclusion in the Manual. It is interesting to note how your committee has broadened the scope of its activity in recent years to cover sanitation matters and the handling of fuel oil, and we appreciate the work which it is doing.

I now excuse your committee with the thanks of the Association. [Applause]

The next committee to report to the Association is Committee 24—Cooperative Relations with Universities. The chairman of this committee is Mr. R. J. Stone, vice president, operations, St. Louis–San Francisco Railway, at St. Louis. Unfortunately, Mr. Stone, with important business to transact for his railroad, was not able to come to our convention this year, and is not available to direct the presentation of his committee, but we are pleased that arrangements were made for the presentation to be made under the direction of the vice chairman of the committee, Mr. W. H. Huffman, assistant engineer of maintenance, Chicago & North Western System. I shall be glad if Mr. Huffman and members of his committee will come to the speaker's table at this time.

Discussion on Cooperative Relations with Universities

[For report, see pp. 571–577.]

[President G. M. O'Rourke presiding.]

VICE CHAIRMAN W. H. HUFFMAN (C&NW): Mr. President, gentlemen: As President O'Rourke has indicated, Mr. Stone was not able to be here. He sent his regrets. He would have liked very much to have presented this report.

The report of Committee 24, which is published in full in the January Bulletin, No. 527, beginning on page 571, will be brief, in order to allow as much time as possible for a panel discussion to follow.

Our report is on three of four assignments, the report on Assignment 4 being a final report on the preparation, publication and distribution of the brochure entitled, "The Railroad Field, A Challenge and Opportunity for Young Engineers", for distribution to college undergraduates and high school counselors.

In addition to Mr. Kellow and his subcommittee, credit and thanks are due to Mr. Grove, Secretary Howard, and to the Public Relations Department and the School and College Service of the AAR for their valuable assistance in the completion, publication and distribution of this brochure.

There will be no oral report on Assignment 1, as that subject will be covered by the panel discussion, but I will now call on R. P. Davis, dean of the College of Engineering, West Virginia University, to comment on the report on Assignment 2.

Assignment 2—Stimulate Among College and University Students A Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities, was presented by Subcommittee Chairman R. P. Davis (West Virginia University).

DEAN DAVIS: Mr. President, fellow Association members, and guests: The report on Assignment 2 deals with the activities of committee members in carrying out the objective of interesting more students in the science of rail transportation.

This is being done through such activities as furnishing speakers for student groups, promoting inspection trips to railroad properties, assisting in placing students in railroad jobs during summer vacations, and assisting in recruitment programs.

The success of these efforts may be magnified many times by members of the Association interesting themselves personally in this objective. We ask for your continued cooperation. This report is presented as information.

PRESIDENT O'ROURKE: It will be so received.

VICE CHAIRMAN HUFFMAN: Thank you, Dean Davis.

Dean Eshbach, of Northwestern Technological Institute, will now comment on the report on Assignment 3.

Assignment 3—The Cooperative System of Education, Including Summer Employment in Railway Service, was presented by Subcommittee Chairman O. W. Eshbach (Northwestern University).

DEAN ESHBACH: Subcommittee 3 took occasion to call your attention to the fiftieth anniversary of the establishment of cooperative education in the United States. This will be celebrated at the University of Cincinnati, April 19 and 20, and we hope that those of you who are interested will attend.

In the report the committee thought it would be interesting to you to review the general circumstances which gave rise to the establishment of the program, the high spots of its development and growth, and its trials during two wars and a depression.

The present thinking and the experience in schools on the question of alternate periods of study and employment is summarized for you, with comment on the present trend, particularly the developments among the larger and better established state institutions from which we draw about two-thirds of our engineers in this country. Finally, there is an appraisal by students who have been through this program within the last 15 years.

We submit this to you for your information.

PRESIDENT O'ROURKE: Thank you, sir.

VICE CHAIRMAN HUFFMAN: Thank you, Dean Eshbach.

We will now have Mr. Kellow's final report on Assignment 4.

I wish to state at this time that Mr. Stone desired to take occasion now to compliment Mr. Kellow and his subcommittee on the splendid work they have done in bringing this assignment to a successful conclusion. I'm sorry to say that Mr. Kellow was called to Seattle Sunday night, and will have to receive his well-deserved plaudits secondhand.

W. A. Oliver, professor of civil engineering at the University of Illinois, will submit Mr. Kellow's report.

Assignment 4—Conduct a Study Looking to the Publication of a Booklet, or Booklets, for Distribution to Educational Groups, Particularly High Schools and Undergraduates in Colleges, Designed to Stimulate Interest in the Opportunities Afforded in a Railroad Engineering Career, was presented by Prof. W. A. Oliver (University of Illinois) in the absence of Subcommittee Chairman G A. Kellow (Milwaukee Road).

[Professor Oliver then read the published report on this assignment.]

VICE CHAIRMAN HUFFMAN: Thank you, Professor Oliver.

The remainder of our assigned time will be used, as indicated previously, for a panel discussion on the subject, "Can the railroads attract and hold an adequate number of qualified engineering graduates in competition with other industries?" Acting as moderator for our panel discussion will be Mr. C. G. Grove, area engineer, Pennsylvania

Railroad, who is extremely well qualified to act in this position, due to his many years of recruiting students for his own railroad.

Mr. Grove is a past chairman of this committee, and a past president of this Association, and, therefore, I am sure he needs no further introduction.

I will ask Mr. Grove to introduce the other members of his panel.

Panel Discussion on

How Can the Railroads Attract and Hold an Adequate Number of Qualified Engineering Graduates in Competition with Other Industries?

C. G. Grove (Pennsylvania): Mr. President and members of the Association: The members of the panel are, from right to left, G. H. Echols, chief engineer of the Southern Railway System; D. W. Tilman, senior assistant engineer, Baltimore & Ohio Railroad; R. P. Davis, dean of the College of Engineering, West Virginia University; and O. W. Eshbach, Dean of the Technological Institute, Northwestern University.

The subject of our discussion is "How can the railroads attract and hold an adequate number of qualified engineering graduates in competition with other industries?" We believe this to be a timely question. It is hoped that our discussion today may clarify some of the issues and lead to a better understanding of the problem on the part of the universities and the railroads.

Mr. Echols, as a railroad member of this panel, do you feel there will be a continuing need for graduate engineers on the railroads? And give your reasons.

G. H. Echols (Southern): Mr. Grove, I feel that this is one of the most vital things that the railroad industry faces today, that is, the acquisition of proper engineering talent from the young folks coming out of school at the present time.

The vitality of our industry 20 years from now will be directly proportional to the number of young men we can attract from the various campuses as graduates.

MR. GROVE: Are you able to recruit each year the number and type of engineering graduates you desire?

Mr. Echols: Not as many as we would like. We probably don't get over 60 to 75 percent of the number we would like to have.

MR. GROVE: Mr. Tilman, do you have any comments to make on these questions I have asked?

D. W. Tilman (B. & O.): I think our need is there. We must have men for replacements due to deaths and retirements. We must have men to replace our losses due to the keen competition from other industries, and from public works agencies.

As far as this year is concerned, we are in pretty good shape as to our engineering needs and our regular employment. Civil engineers for construction, maintenance and surveying are generally available, more so than they have been in previous years, but in our training program, where we need civil, electrical, mechanical and industrial engineers, the going isn't so good.

MR. GROVE: Dean Eshbach, there is concern about the shortage in engineering graduates generally. Does this shortage apply to engineers who are seeking employment with the railroads, also?

Dean O. W. Eshbach (Northwestern University): Yes. The shortage will be alleviated slightly in the next few years, but the railroads will have to capitalize on their traditional employment, which has been in the field of civil engineering, and this is a pretty sad picture.

I think everyone here should realize that the percentage of students enrolling in civil engineering is dropping, while there is a slight increase in all registrations. For example, in the senior year there will be about 70 percent civil engineers; in the junior year, 50; in the sophomore year, 13; and in the freshman year, about 11. This means you will be faced with increasing difficulty the next few years in having a proper supply, particularly in civil engineers.

MR. GROVE: Mr. Echols, to what do you attribute your success in recruiting engineers for railroad service?

Mr. Echols: I said a while ago, Mr. Grove, that we were able to get only 60 to 75 percent, probably, of what we would like to have, so your question as to "success" is a bit contradictory to the facts.

However, we endeavor to look at the qualifications of a man other than his engineering training or his school work. We think that a man who joins a student training program should be a man of heart. He is to be among the men from whom we will choose our officers in the future. That man should have the desire to work practically day and night..You know, that's what you and I did, to start with. We try to choose the kind of man who has the interests of the railroad at heart; who really wants to make railroading his life work.

When you get a fellow like that, you very seldom lose him. He stays with you, and he can outperform or outthink two of any other type.

MR. GROVE: Mr. Tilman, what has been your experience in this regard?

Mr. Tilman: Our success is partly due to the fact that we use men with engineering background and experience to do the recruiting. In this way prospective candidates can be clearly told what we do and how we do it. I think that is important—that the man know just what he has to look forward to.

MR. GROVE: Dean Davis, how do the railroads measure up with other industries in their recruiting methods? Can you give us a comparison, and tell us how the railroads can help themselves? Are the railroads aggressive enough?

Dean R. P. Davis (West Virginia University): The recruitment methods of the railroads do not differ materially from those of other industries. The individual railroads do not seek as many graduates as some of the larger manufacturing companies, and so their recruitment programs are sometimes not as highly organized.

Your success will depend largely on the type of representative you send out. He should have an attractive personality, should have a natural liking for youth, and should speak with authority on matters pertaining to railroading.

MR. GROVE: Dean Eshbach, is industry offering inducements to engineers that are more promising than those offered by the railroads? What must we do to match or beat their offers?

Dean Eshbach: From a salary standpoint, I think I'd say you're about comparable. The offerings today are somewhere between $4000 and $5000 a year.

There is another factor which is going to increase the difficulty in the next couple of years, and you should be aware of it. In the last 10 years in this country the expenditures in development and research in industry have risen from a billion to about five billion dollars a year, and the shortage that everyone is going to experience in the availability of engineers will be due in large measure to the demands which this activity is making for the best men who are being graduated from the colleges. It is increasingly demanding those with masters' and doctors' degrees. Industries are offering financial subsidies for men to go on with these programs. They are following students from the time they are undergraduates until they graduate.

This takes away from the already short supply the very best talent. That is a good thing from the standpoint of the country, but you have to face this competition.

I believe if you capitalize on the idea, and sell it to students and to the public, that the railroads are and always have been a very vital part of our economy, and that, managerially and in engineering work, they will always have challenging opportunities for young men, you can lessen the competition to your betterment—but only with good, hard work.

MR. GROVE: Mr. Echols, in view of what has been said, what do you think the railroads should do to improve their recruiting position?

MR. ECHOLS: Mr. Grove, I think that we, as engineers, are notoriously bad salesmen. You know that when you do get a good engineer who is a good salesman, he's pretty soon on the top floor of his building; he's running the show. But, generally speaking, we engineers are very poor salesmen.

On the other hand, some of the other industries that are competing with us for the services of technical graduates have very good salesmen. For instance, in the aeronautics and automobile industries they sell them on the glamour of the profession and their work. Forty or fifty years ago, the railroads had that glamour for the youngsters; now it's the electronics boys. What we have to do is to tell these youngsters that their future in railroads—and I really believe it—the future for young men in the railroad industry of America, with the mechanization that we have facing us, is greater than it has ever been before. We have just scratched the surface so far as mechanization in yards, main line movements, maintenance of way, etc., are concerned. We should sell them on the idea that "thar's gold in them thar hills." All they have to do is get in and scratch with the railroads, and there's plenty for them to do and plenty of good future ahead for them.

I think we can out-glamour the glamour boys by telling them about the push-button yards we have, for instance. They don't know that we use electronics. Some of these youngsters think that the latest thing the railroads have done was the installation of the slot in the Pullman car where you can drop used safety razor blades. We're responsible for that. We should tell the world what we've got and what we intend to do.

MR. GROVE: Dean Davis, do you think that the training programs in effect on some railroads, similar to programs under way by industry, are worth while or essential for young engineers desiring to work for the railroad?

MR. DAVIS: I believe training programs are worth while. Graduation from college means that a boy has had four years or more of systematically organized study, and we need a gradual transition from this type of learning to the one in which the young man is on his own.

MR. GROVE: There has been considerable comment in the educational field, and among the students particularly, concerning the training programs that are in effect on some of the railroads. The question we are discussing this morning is one that does not apply with equal emphasis to all railroads, but many of the railroads have used training programs, and effectively. However, there is a question in the minds of some students as to whether they want to spend additional time—an additional two or three years—easing into their jobs on a railroad. Generally speaking, where the training program is effectively set up and carried out, it has many advantages during that transition period.

Mr. Tilman, do you experience difficulty in holding graduate engineers after they have entered the service? If so, what are the predominating causes for their leaving, and what can be done to remedy the situation?

MR. TILMAN: Yes, we do have that trouble, Mr. Grove. We have considerable difficulty in holding our engineers. In my opinion, this is because of the slow promotion, and the inadequacy of the present salaries in the middle brackets. It is also due to the absence of sliding salary scales.

A formal program of promotion, based on merit, would help. Unnecessary and frequent moving around of the men is objectionable in some cases, particularly among the married men. But aside from these factors, other industries can usually induce our young men to come to them with the lure of high salaries.

MR. GROVE: Mr. Echols, do you think that the brochure this Association has prepared and distributed will help us in the recruiting of young men to enter the service of our companies?

MR. ECHOLS: Yes, Mr. Grove, I do. I think it will be of tremendous service. However, the distribution of a brochure, to my way of thinking, must be similar to broadcasting seed. You must distribute a tremendous number of brochures to be sure some of them will fall on fertile soil. Some will be picked up and read with interest, but those will be few and far between. Therefore, we should have a tremendous number to broadcast, so that a sizable number of them will fall in the right spots.

MR. GROVE: Gentlemen, we have presented this subject in a general way for your consideration, and we feel that there are people in this audience who are interested and who may like to ask questions. Whether we will be able to answer your questions remains to be seen, but for a short period we will entertain any questions that you may have on this subject.

QUESTION: All of this discussion has been about competition for graduate and student engineers in our colleges. It has been reported that the AREA was going to send one copy of the brochure to high school counselors, if requested. **Does the committee recognize the fact that the shortage of engineers is due largely to the fact that these young men don't go to college to be engineers? Do you think that one copy, upon request, is adequate to interest high school students in becoming engineers? I'd like to find out, because that's quite a question in our local high school today.**

MR. GROVE: At the time of the publication of this brochure we had in mind publishing two, one for undergraduates in colleges and universities, and one for use in high schools, but due to many reasons—among which was the question of finances—it was concluded that we would first publish this brochure primarily for the undergraduates in colleges and universities, but that we would have some distribution in the high schools.

It is my opinion, based on my own personal experience, that an individual who is going to seek an engineering degree, or who is going to college and isn't certain as to just what he is going to do, is much influenced by information which might be available to him in his senior year in high school.

As to the distribution of this brochure to date, and the lack of copies for the high schools, I believe Secretary Howard can best give you the information you request.

Executive Secretary Howard: Mr. Grove is correct that consideration was given to publishing two brochures, and for the reasons he stated, it was decided to start off with this one brochure, to go to the undergraduates in colleges. I don't know that the committee has given up entirely the idea of ultimately producing a second brochure better adapted to high school students.

Through a publication addressed to high school counselors we offered one or two of the brochures to any counselors who requested them, and to date we have received requests from about 150. Frankly, that is much smaller than we anticipated, and we know that we are not doing the job in this tremendously large pre-college student field. But it was felt that the Association could not afford to take on at this ime the largely increased cost which would be involved.

Dean Eshbach: Mr. Grove, might I comment on that question?

In the matter of high school information guidance, I think there is a real problem which I hope all of the counselors in high schools will analyze and determine for themselves, as to the actions they should take in the public interest.

I think when any industry makes information available about its business, the first responsibility of the educator is to weigh the value of the educational program, and the public should acquire the material for the benefit of students and pay for it. No organization could afford to send out a million brochures, for example, or something like that, to the high schools; nor would the high schools want it.

One of the real problems in this whole picture is this, that young boys of promise in this country are being denied the opportunity of being participants in one of the finest romances in our civilization in the time in which they are going to be active, by the lack of proper information as to what their opportunities are, and the lack of the proper kinds of courses in high school, so that when they go to college they will have the opportunity, at a more mature age, of studying the things they should study to compete.

Another reason, of course, is the lack of information as to how they can work their way through school. Many students give up before they start because they don't think they can go to college. We are losing more than half of the talent in this country because of misinformation.

Dean Davis: Mr. Grove, I'd like to comment on this point. I'm not too strong for the railroads' going all out to get the high school youngsters to take up engineering in order to go specifically into railroad engineering work, but I believe that if the railroads, along with many other agencies, would stress the importance of the physical sciences to the high school students—mathematics, chemistry and physics—I believe we would get lots more engineers in the colleges, and there would be many more men to take up railroad work. I think the railroads would get their fair share.

Mr. Grove: We're limited by time in this important discussion, but in summing up the situation as it appears to me today, I would like to say that while the railroads are not at the present time an expanding organization such as some of the industries with which we compete, which are seeking young men in colleges and universities, there are opportunities for young men in engineering and managerial capacities on the railroad now, and there always will be such opportunities. If we can get to the young men who

are interested and willing to accept the challenge that railroading offers to them, we will be able to secure and retain them in our service.

This problem is unique in that it doesn't apply with equal intensity to all railroads. Some of us are able to secure as many graduates as we want. Our panel question can be answered in two ways. First, we must have an adequate starting salary that will enable us to compete with other industries in getting these young men to come with us, and second, we must show them by the experience of others that they will have a chance to advance to positions of responsibility equalling those in other industries. If we do these two things we will have no trouble securing and keeping them.

My time is up, although I know that there is much more that could be said on this subject. Thank you for your attention, and thank you, the members of the panel. Mr. President, that concludes our presentation.

PRESIDENT O'ROURKE: Thank you very much, Mr. Grove. It was an excellent presentation.

Now, Mr. Huffman, you may have the floor.

VICE CHAIRMAN HUFFMAN: Thank you very much, gentlemen, for a most interesting discussion. Thanks to the audience for its attention and contribution.

Mr. President, that completes the presentation of the report of Committee 24.

PRESIDENT O'ROURKE: Thank you, Mr. Huffman. The Association is very appreciative of the work of your committee in its effort to stimulate greater appreciation on the part of railway managements in selecting graduates from the colleges and universities, on the one hand, and to stimulate among college and university students a greater interest in the science of transportation, on the other hand. No doubt, in the latter regard, your committee made a great contribution in the publication during the past year of the engineer recruitment brochure entitled, "The Railroad Field—A Challenge and Opportunity for Young Engineers."

According to the Secretary's report, 10,000 copies of the brochure were made available to the School and College Service of the Public Relations Department of the AAR for selected distribution, and 15,000 copies were published for distribution by the AREA over the next three years. Up to December 31, 1955, 5140 copies had been distributed free by the Association to engineering schools of the United States and Canada, and other interested parties, and another 2103 had been sold to the railroads for use in their own recruitment efforts.

I congratulate your committee both upon the quality and wide distribution of this brochure, which, unquestionably, will turn some graduates toward railroading as a career, while informing hundreds of others that there is still a great rail transportation industry in the country which offers attractive opportunities for technical graduates.

Your panel discussion here this morning has been most interesting, and while it would indicate that some railroad managements appreciate the necessity for recruiting graduate engineers and taking the necessary steps to hold them, it is evident that there is still much to be done in this regard by the railroad industry as a whole, if it is to compete successfully with other industries for the necessary number of qualified engineers from the graduating classes of our technical institutions.

Thank you for your important contribution of the last year, and for your interesting convention presentation. Your committee is now excused with the thanks of the Association. [Applause]

Turning from the subject of manpower, we will next consider a number of reports dealing with structures and materials. The first of our committees to report on such

subjects is our Committee 7—Wood Bridges and Trestles, of which W. C. Howe, engineer of bridges and buildings, Bessemer & Lake Erie Railroad, at Greenville, Pa., is chairman. Since Mr. Howe could not be with us today, due to illness, the presentation of the committee will be under the direction of the vice chairman of the committee, Mr. S. L. Goldberg, structural engineer, Northern Pacific Railway. May I ask that Mr. Goldberg and the members of his committee come to the platform? And again, may I ask that those subcommittee chairmen to make reports take places near the podium.

Discussion on Wood Bridges and Trestles

[For report, see pp. 565–570.]

[President G. M. O'Rourke presiding.]

Vice Chairman S. L. Goldberg (Northern Pacific): Mr. President, members of the Association and guests: Your committee reports on three assignments, published in Bulletin 527, January 1956, pages 565 to 570, incl.

Subcommittee Chairman R. E. Jacobus, bridge and building supervisor, Illinois Central Railroad, will present a progress report on Assignment 4—Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints.

Assignment 4—Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints, Collaborating with Committees 6 and 17 and with the Fire Protection and Insurance Section, AAR, was presented by Subcommittee Chairman R. E. Jacobus (Illinois Central).

Mr. Jacobus: Under this assignment, your committee, collaborating with the AAR Research Center, has continued the testing of specimens, and the development of instrumentation, equipment and testing techniques.

A tentative specification for fire-retardant coating materials is being developed, and correlation studies between laboratory testing and full-scale field testing have been started.

The 1956 program expects to complete certain parts of the testing, together with evaluation of data.

This report is submitted as information.

President O'Rourke: It will be so received. Thank you, sir.

Vice Chairman Goldberg: Thank you, Mr. Jacobus.

Subcommittee Chairman W. A. Oliver, professor of Civil Engineering, University of Illinois, will present a progress report as information on Assignment 6.

Assignment 6—Design of Timber-Concrete Composite Decks, Collaborating with Committee 8, was presented by Subcommittee Chairman W. A. Oliver (University of Illinois).

Prof. Oliver: This year we wish to report progress. Next year we expect to submit designs and design procedures for consideration as Manual material.

At this time I might call the attention of the members of the AREA to the fact that this form of construction is not new on the railroads—that is, composite concrete–wood construction. A very casual survey of two or three of the major railroads indicated something over 3200 lin ft of this concrete–timber construction.

For those of you who are or may be interested in obtaining additional information concerning this form of construction, I would refer you to a paper by T. K. May of the West Coast Lumbermen's Association, which we published a year ago as our progress

report. This was published, of course, in the Bulletin and later in the Proceedings of the Association.

PRESIDENT O'ROURKE: Thank you, sir.

VICE CHAIRMAN GOLDBERG: Thank you, Professor Oliver.

At this time I will present the report of the subcommittee on Assignment 7, of which I am the subcommittee chairman.

Assignment 7—Means of Conserving Labor and Materials, Including the Adaptation of Substitute Noncritical Materials, and Specifications for the Reclamation of Released Materials, Tools and Equipment, Collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR, was presented by Subcommittee Chairman S. L. Goldberg (Northern Pacfiic).

MR. GOLDBERG: Suggestions for conserving both labor and material have appeared in previous published reports by this committee. Nothing new has been developed. Subcommittee 7 has recommended that this assignment be dropped from its work agenda.

However, at this time I would like to call to your attention the number of ways that have been recommended by the lumber industry for obtaining greater economy in the use of timber. By specifying sizes and grades that are outlined in standard grading rules of desired species, greatest economy and ease of procurement are obtained. Nonstandard sizes require manufacturers to change their normal production line; those pieces that don't meet the required grade must be remanufactured at extra cost, in order that they may be sold on the commercial market. By the same token, specifying lumber in the smaller sizes also requires special manufacture, and those that don't meet specified grade or any excess are not readily marketable. A quantity order of timber in random lengths is usually lower in price than orders of pieces all one length. As the average length of a log is 32 ft, longer pieces are less readily available, but pieces over 20 ft long usually command a higher unit price.

Sometimes lower grades have structural advantages; a larger size will carry the same load with less deflection and increased horizontal shear resistance.

This is a final report, submitted as information.

PRESIDENT O'ROURKE: Thank you, it will be so received.

VICE CHAIRMAN GOLDBERG: We have arranged for two speakers in connection with the subject of glued laminated lumber. Mr. F. E. Schneider, assistant engineer, Santa Fe, and a very able subcommittee chairman of the committee, prepared the specifications of glued laminated lumber, and will present our speakers for this special feature.

F. E. SCHNEIDER (Santa Fe): Mr. President, members and guests of the AREA: Last year a specification for glued laminated lumber was adopted, which now appears in the Manual. This year we are starting on an assignment to work up designs for glued laminated bridges and trestles.

To arouse interest in this type of lumber, our committee obtained permission to set up an exhibit and present two special features to prepare the structural engineer to think in terms of higher unit stresses and greater adaptability of this new type of lumber.

Before introducing our speakers, I'd like to call your attention to the laminated lumber exhibit in the foyer, directly across from the registration desks. The exhibit shows the flexibility of this product. It shows that it can be treated, can be exposed to the weather, and made up in any sizes or lengths. I suggest that you spend at least a few minutes at the exhibit on your way out, as I think you will find it of great interest.

Our first speaker is Alan D. Freas, an engineer in the Division of Physics and Engineering of the Forest Products Laboratory. He will tell us about the development of working stresses for glued laminated lumber.

Development of Working Stresses for Glued Laminated Lumber

By Alan D. Freas

Engineer, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

Introduction

Glued laminated lumber is becoming increasingly important in many fields of construction, including those of interest to the railroads. It is essential, therefore, in the interests of both efficiency and economy, that working stresses for laminated lumber be as accurate as possible.

The U. S. Forest Products Laboratory, as a part of its overall objective of improved utilization of the products of the Nation's forests, has a vital interest in all phases of the laminating problem. The development of methods for establishing working stresses has been an essential part of the Laboratory's laminated lumber research. This paper will present the elements of the procedures recommended by the Laboratory.

Basic Stresses

Basic stresses are those which would be suitable for design with material containing no strength-reducing features such as knots, cross grain, and the like. Basic stresses for solid sawn lumber have been in existence for some years and were developed from test data by applying appropriate factors to reduce the test averages to a level suitable for design. The most important factors considered in the reduction are variability, period of loading, and factor of safety. Since these factors will of necessity be involved in laminated construction, the basic stresses for laminated lumber to be used under conditions leading to high moisture content should be the same as for solid sawn lumber (Table 1).

There is, however, a basic difference between solid sawn and glued laminated lumber that must be considered. To produce high-quality glued joints, the lumber used in laminating must be at a relatively low moisture content—generally less than 15 percent. Further, the lumber is seasoned in thicknesses of 2 in or less so that, with reasonable care, drying defects are minimized. Thus, glued laminated lumber goes into service at a low moisture content in contrast to large solid timbers, for which seasoning prior to service is impractical. Further, the seasoning degrade, which reduces the strength of large timbers, is essentially eliminated.

For those applications in which the moisture content may be expected to remain low, as in most covered structures, credit is given for the higher strength of dry wood. This is reflected in a second set of basic stresses (Table 2).

The same factors considered in deriving the basic stresses of Table 1 apply equally to stresses for use in dry locations. The stresses of Table 2, therefore, are derived from those of Table 1 by multiplication by a factor reflecting the effect of the lower moisture content on strength.

Extensive tests provide relationship between the strength of dry and green wood. These relationships vary somewhat among different species and considerably among the various properties. A study of these relationships indicated that it was suitable to use average values representing changes in strength with moisture content for a group of

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Table 1.--Basic stresses for structural members laminated from clear material and under long-time service at maximum design load and under dry conditions, as in most covered structures, for use in determining working stresses according to grade of laminations and other applicable factors

Species[1]	Extreme fiber in bending or tension parallel to grain	Maximum longitudinal shear	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity in bending
(1)	(2)	(3)	(4)	(5)	(6)
	p.s.i.	p.s.i.	p.s.i.	p.s.i.	1,000 p.s.i.
SOFTWOODS					
Baldcypress (southern cypress)	2,400	170	330	2,000	1,300
Cedars					
Redcedar, western	1,600	135	220	1,300	1,100
White-cedar, Atlantic (southern white cedar) and northern	1,400	115	195	1,050	900
White-cedar, Port Orford	2,000	150	275	1,650	1,600
Yellow-cedar, Alaska (Alaska cedar)	2,000	150	275	1,450	1,300
Douglas-fir, coast type	2,750	150	350	2,000	1,800
Douglas-fir, coast type, close-grained	2,950	150	375	2,150	1,800
Douglas-fir, Rocky Mountain type	2,000	135	310	1,450	1,500
Douglas-fir, all regions, dense	3,200	150	410	2,350	1,800
Fir, California red, grand, noble, and white	2,000	115	330	1,300	1,200
Fir, balsam	1,600	115	165	1,300	1,100
Hemlock, eastern	2,000	115	330	1,300	1,200
Hemlock, western (West Coast hemlock)	2,400	125	330	1,650	1,500
Larch, western	2,750	150	350	2,000	1,600
Pine, eastern white (Northern white), ponderosa, sugar, and western white (Idaho white)	1,600	135	275	1,400	1,100
Pine, jack	2,000	135	240	1,450	1,200
Pine, lodgepole	1,600	100	240	1,300	1,100
Pine, red (Norway pine)	2,000	135	240	1,450	1,300
Pine, southern yellow	2,750	180	350	2,000	1,800
Pine, southern yellow, dense	3,200	180	410	2,350	1,800
Redwood	2,200	115	275	1,850	1,300
Redwood, close-grained	2,400	115	295	2,000	1,300
Spruce, Engelmann	1,400	115	195	1,100	900
Spruce, red, white, and Sitka	2,000	135	275	1,450	1,300
Tamarack	2,200	160	330	1,850	1,400
HARDWOODS					
Ash, black	1,800	150	330	1,150	1,200
Ash, commercial white	2,550	210	550	2,000	1,600
Beech, American	2,750	210	550	2,200	1,800
Birch, sweet and yellow	2,750	210	550	2,200	1,800
Cottonwood, eastern	1,400	100	165	1,100	1,100
Elm, American and slippery (white or soft elm)	2,000	170	275	1,450	1,300
Elm, rock	2,750	210	550	2,200	1,400
Hickory, true and pecan	3,500	235	660	2,750	2,000
Maple, black and sugar (hard maple)	2,750	210	550	2,200	1,800
Oak, commercial red and white	2,550	210	550	1,850	1,600
Sweetgum (red or sap gum)	2,000	170	330	1,450	1,300
Tupelo, black (blackgum)	2,000	170	330	1,450	1,300
Tupelo, water	2,000	170	330	1,450	1,300
Yellow-poplar	1,600	135	240	1,300	1,200

[1] Species names from approved check list, U. S. Forest Service, 1944. Commercial designations are shown in parentheses.

species. Since there is some variation among species and even within a single species, only about one-half of the average increases for various properties between the green and dry condition was used in deriving the basic stresses of Table 2. For example, the stress in extreme fiber in bending is about 50 percent higher for dry than for green, small, clear specimens. Therefore, the basic stress is 25 percent higher in Table 2 than in Table 1. Similarly, the modulus of elasticity averages about 20 percent higher in dry than in green material, and the basic value is taken as 10 percent higher.

Effect of Knots on Strength

Extensive tests have provided an empirical relationship that shows the effect of knots on the bending strength of laminated members. Basically, this relationship shows

Table 2.--Basic stresses for structural members, laminated from clear material and under long-time service at maximum design load and under wet conditions, for use in determining working stresses according to grade of laminations and other applicable factors

Species[1]	Extreme fiber in bending or tension parallel to grain	Maximum horizontal shear	Compression perpendicular to grain	Compression parallel to grain l/d = 11 or less	Modulus of elasticity in bending
(1)	(2)	(3)	(4)	(5)	(6)
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.
SOFTWOODS					
Baldcypress (southern cypress)	1,900	150	220	1,450	1,200
Cedars					
Redcedar, western	1,300	120	145	950	1,000
White-cedar, Atlantic (southern white cedar) and northern	1,100	100	130	750	800
White-cedar, Port Orford	1,600	130	185	1,200	1,500
Yellow-cedar, Alaska (Alaska cedar)	1,600	130	185	1,050	1,200
Douglas-fir, coast type	2,200	130	235	1,450	1,600
Douglas-fir, coast type, close-grained	2,350	130	250	1,550	1,600
Douglas-fir, Rocky Mountain type	1,600	120	265	1,050	1,200
Douglas-fir, all regions, dense	2,550	130	275	1,700	1,600
Fir, California red, grand, noble, and white	1,600	100	220	950	1,100
Fir, balsam	1,300	100	110	950	1,000
Hemlock, eastern	1,600	100	220	950	1,100
Hemlock, western (West Coast hemlock)	1,900	110	220	1,200	1,400
Larch, western	2,200	130	235	1,450	1,500
Pine, eastern white (Northern white), ponderosa, sugar, and western white (Idaho white)	1,300	120	185	1,000	1,000
Pine, jack	1,600	120	160	1,050	1,100
Pine, lodgepole	1,300	90	160	950	1,000
Pine, red (Norway pine)	1,600	120	160	1,050	1,200
Pine, southern yellow	2,200	160	235	1,450	1,600
Pine, southern yellow, dense	2,550	160	275	1,700	1,600
Redwood	1,750	100	185	1,350	1,200
Redwood, close-grained	1,900	100	195	1,450	1,200
Spruce, Engelmann	1,100	100	130	800	800
Spruce, red, white, and Sitka	1,600	120	185	1,050	1,200
Tamarack	1,750	140	220	1,350	1,300
HARDWOODS					
Ash, black	1,450	130	220	850	1,100
Ash, commercial white	2,050	185	365	1,450	1,500
Beech, American	2,200	185	365	1,600	1,600
Birch, sweet and yellow	2,200	185	365	1,600	1,600
Cottonwood, eastern	1,100	90	110	800	1,000
Elm, American and slippery (white or soft elm)	1,600	150	185	1,050	1,200
Elm, rock	2,200	185	365	1,600	1,300
Hickory, true and pecan	2,800	205	440	2,000	1,800
Maple, black and sugar (hard maple)	2,200	185	365	1,600	1,600
Oak, commercial red and white	2,050	185	365	1,350	1,500
Sweetgum (red or sap gum)	1,600	150	220	1,050	1,200
Tupelo, black (blackgum)	1,600	150	220	1,050	1,200
Tupelo, water	1,600	150	220	1,050	1,200
Yellow-poplar	1,300	120	160	950	1,100

[1] Species names from approved check list, U. S. Forest Service, 1944. Commercial designations are shown in parentheses.

that the strength is dependent upon both the size and the position of the knots with respect to the natural axis. The combination of size and position is best represented by moment of inertia. It has been found also that knots near a given cross section act as if they were all at that cross section. The most direct relationship, therefore, is between strength and the moment of inertia of the areas occupied by knots within a distance of 6 in on either side of the cross section in question. Thus, if the sizes and the locations of the knots in a laminated beam or arch are known, the loss in strength may be found, and the strength ratio or proportion of strength remaining can be calculated from this figure.

Obviously, it is impractical to design a structure without knowing the strength until the boards to make it have been assembled and the knots positioned and measured.

It is equally impractical to tailor a beam to have knots of specified size in particular positions. Instead, some way of estimating the strength of a random assembly of pieces is essential.

Various possible assumptions as to knot size and position in a random assembly were considered and discarded. Since a random assembly was involved, the use of a statistical method was indicated. Accordingly, the method recommended is based on a statistical approach.

Statistical data on knot size are gathered by studying a sample of the grade in question. From such a study, it is possible to predict the sum of knot sizes in 1-ft lengths which have any given probability of occurrence. A combination of this information and that on the effect of position with respect to the neutral axis of a beam permits the prediction of the value of moment of inertia of the areas occupied by knots in any 1-ft length that has any given probability of occurrence. After a level of probability suitable for use in design is chosen, the strength relationship mentioned earlier may be used to obtain the strength ratio having that probability. The product of this strength ratio and the basic stress gives a working stress.

The probability that knots will concentrate and give a large value of moment of inertia, and thus a small strength ratio, decreases with the number of laminations assembled. This is illustrated in Fig. 1, which gives strength ratios for two grades with various numbers of laminations. The effect of knot dispersion is clearly indicated. Even with small numbers of laminations, strength ratios are higher than for the same grade used as a solid beam, and the advantage increases with the number of laminations.

In columns and tension members, there is no effect of position, as in a beam, so that strength is related to knot size rather than to moment of inertia. There is, however, an effect of dispersion for members of this type also, so that strength ratios are higher than for a comparable solid member and increase with the number of laminations.

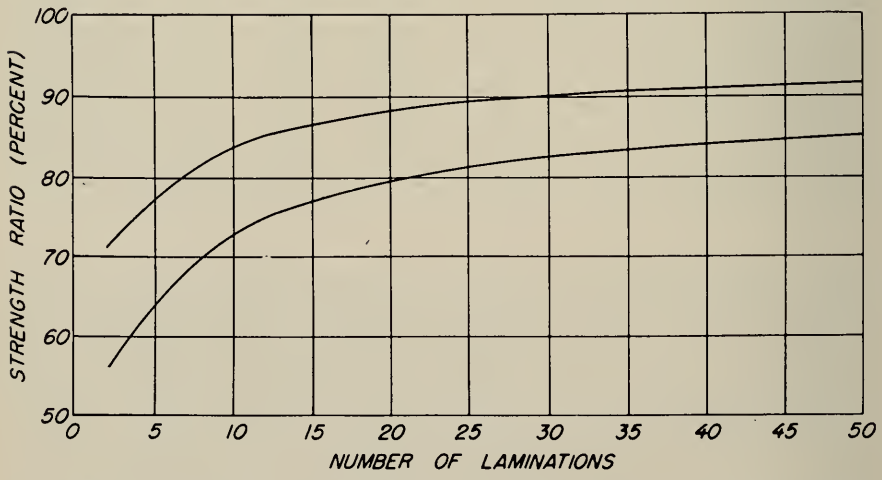


Fig. 1—Sample plot of strength ratios for laminated bending members containing various numbers of laminations as based on a survey of knot size and location. The member was made up of two typical grades of lumber.

Cross Grain

Since cross grain is an important factor in determining strength in laminated as well as in solid members, it must be appropriately limited. After establishing a working stress from a statistical analysis of knot frequency, cross grain can be limited so that its strength ratio is at least as high as that based on knots.

Cross grain limitations are, of course, most important in the outer laminations of beams and arches and may be eased in the inner laminations.

The effect of the dispersion of knots in increasing the strength ratio and the working stress in laminated members as compared with solid members of comparable grade raises a special problem with respect to cross grain. In the case of solid timbers, the limitations on knots and on cross grain are generally so set as to give about the same strength ratio for both. When such grades are laminated, the effect of dispersion is to increase the strength ratio based on knots without a change in knot limitations. Accordingly, the limitation on cross grain must be made more rigid to compensate for the higher working stress. Generally, this is important only in the outer groups of laminations, say the outer 10 percent, since the original limitations are suitable for the balance of the beam. In a column or tension member, however, the more rigid limitations must apply to all laminations.

End Joints

End joints in the individual laminations are required for members longer than available lumber lengths. In effect, they are required in all structural members. The ability of end joints to transmit stress is a vital factor in determining the stress which may be used in design.

End joints vary greatly in efficiency, depending upon such factors as the type and form, the slope of the adjoining parts, and the quality of fabrication. Practically speaking, plain glued scarf joints are the only type used in important structural members. They vary considerably in efficiency, depending upon their slope, from about 60 percent for a slope of 1 in 5, to about 90 percent for a slope of 1 in 12, for bending stresses. Scarf joints of identical slopes are more efficient for compression members than for bending members.

It is obvious that the high strength available in laminated members cannot be realized if inefficient end joints are used. After establishing a working stress based on the distribution of knots as discussed earlier, it becomes necessary to choose a limiting scarf-joint slope that will justify the design stress. Industry and AREA standards thus specify, in connection with tables of design stresses, the steepest scarf joint that may be used.

Shear Strength

Solid, one-piece timbers of large cross section characteristically develop deep checks as they season in service. Such checking reduces shear strength because the area available to resist shear is reduced. Laminated beams, however, go into service thoroughly seasoned and thus may be expected to check but little. Further, since the laminations are generally flat-grained, such checks as may develop will, by and large, lie in a vertical plane and thus will have little effect on shear strength. For these reasons, design stresses for shear are commonly taken equal to the basic stresses; that is, there is no reduction for grade.

This higher shear strength is of particular importance in such applications as trestle stringers and caps, where shear is generally critical. For this reason and because the large

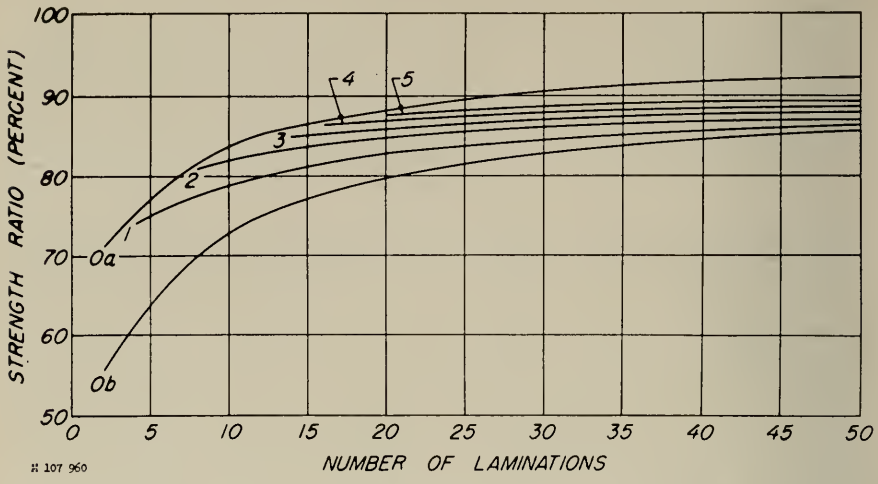


Fig. 2—Sample plot of strength ratios for laminated bending members containing various numbers of laminations as based on a survey of knot size and location. Two typical grades of lumber were used in various combinations, and the curve numbers indicate the number of laminations on each side that are of higher grade, except curve *Oa* representing beams in which all laminations are of higher grade, and curve *Ob* in which all are of lower grade.

sizes required are more readliy available, laminated members offer particular promise in trestle construction.

Combination of Grades

Laminating offers a possibility not realizable with solid material—the sorting of material for most advantageous use. Thus, it is more sensible to use laminations of higher grade in the outer, more highly stressed laminations than in the inner, less highly stressed laminations. Research has demonstrated that substantial proportions of low-grade laminations may be used without serious overall loss of strength in the beam as compared to a beam made entirely of the higher grade laminations.

The statistical analysis mentioned earlier can be used with combinations of grades, taking into account not only the distribution of knot sizes but also the position of the laminations with respect to the neutral axis. This effect is illustrated in Fig. 2, which shows strength ratios for various combinations of two grades. Even small proportions of a higher grade in the beam effect substantial improvements in strength as compared to a beam made completely of the lower grade. The effect is even more pronounced if the outer laminations are free of knots (Fig. 3).

Industry-Recommended Working Stresses

The Laboratory does not undertake to establish working stresses for the lumber industry. Rather, it is concerned, as for solid timbers, with the establishment of proper procedures. The lumber industry, however, has used the principles described earlier in establishing design stresses like those included in Table 1 of the AREA Specifications for Glued Laminated Lumber. A comparison of stresses in this table with those for

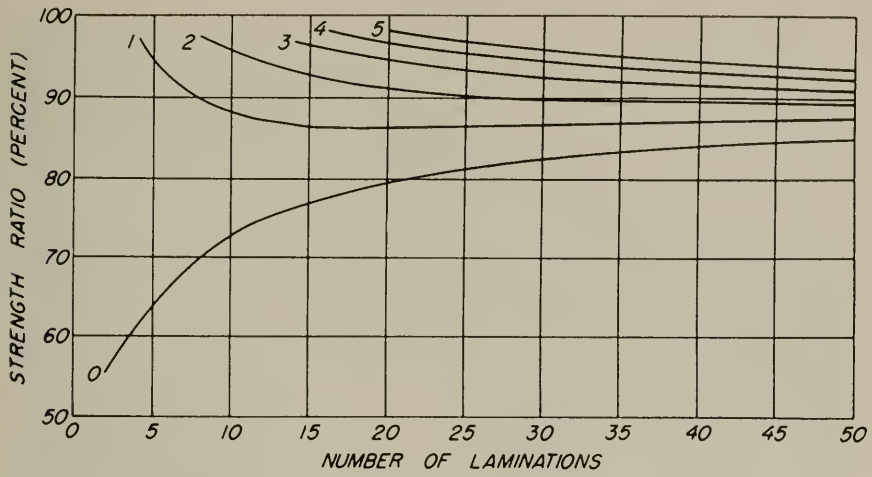


Fig. 3—Sample plot of strength ratios for laminated bending members containing various numbers of laminations as based on a survey of knot size and location. A typical grade was used for the inner laminations and was combined with defect-free outer laminations. The curve numbers indicate the number of clear laminations on each side.

comparable solid grades shows the substantial increases in stress permissible for laminated construction, particularly for dry conditions of use.

Summary

The development of working stresses for glued laminated construction is somewhat complex. Substantially higher working stresses are suitable, particularly for dry locations of use. The possibility of combining grades is an important advantage, both in improving working stresses and in economizing by the use of some lower grade material.

Design stresses based on the procedures described are relatively new. As experience in the use of these stresses accumulates, modifications may be possible.

The whole subject of laminating will be of increasing importance to the railroad industry, particularly to those concerned with wood bridges and trestles. Innumerable other applications, in roundhouses, freight sheds, light buildings, and the like are distinct possibilities and should not be overlooked.

Vice Chairman Goldberg: Thank you, Mr. Freas.

Our second speaker is Mr. Frank Hanrahan, executive vice president, American Institute of Timber Construction, and a member of our committee. Mr. Hanrahan will tell us about the use of glued, laminated lumber by the railroads.

Use of Structural Glued Laminated Lumber by Railroads

By Frank J. Hanrahan
Executive Vice President, American Institute of Timber Construction

Structural glued laminated lumber has been used in Europe for railway structures such as concourses of important railway stations, roofs for station platforms, locomotive and streetcar barns, car repair shops, vehicular and pedestrian bridges, erection forms for stone and concrete bridges, etc., for nearly 50 years.

Twenty years ago, T. R. C. Wilson of the U. S. Forest Products Laboratory, after inspection of some 50 such structures, which at that time had been in service up to about 30 years in Sweden, Norway, Denmark, Germany and Switzerland, said (The Glued Laminated Wooden Arch, USDA Technical Bulletin No. 691):

"The use of glued laminated arches and other members in American structures was suggested by the favorable record of glued construction in Europe."

E. J. Ruble of the AAR Research staff in reporting (page 1074, 1955 AREA Proceedings) on five American test installations of glued laminated stringer railroad bridges, the earliest of which was installed in October 1944, said:

"All in all, I would say that the laminated stringers and timbers are proving very satisfactory."

Likewise, he reported favorably on the weatherometer tests thereon. Also, the U. S. Forest Products Laboratory reported that the results of shear tests, conducted on specimens tested before and after several years of weathering, were satisfactory. Additional information is given in AREA literature (pages 382–385, 1947 Proceedings; pages 568–582, 1954 Proceedings).

Committee 7 developed, and AREA adopted last year for inclusion in the Manual (page 1071, 1955 Proceedings), "Specifications for Structural Glued Laminated Lumber." They assure a good quality product for each intended use. They reflect the findings from extensive research and the developments made and experience acquired over many years by an industry specializing in the design, fabrication and erection of such engineered timber structures of all kinds.

Wood construction is no longer limited by what can be sawn from a tree. Today the size and shape of timber elements and assemblies are limited only by transportation and erection facilities. Glued laminated lumber combines economically both beauty and structural function. It can be treated before or after assembly and gluing. It will withstand any exposure or service that sawn timber will. As indicated by Mr. Freas, it has much higher allowable working stresses.

Erection and maintenance time is less because the desired camber can be built into the beam while laminating; close tolerances can be maintained, thereby eliminating or reducing shimming and adzing, and permitting more prefabrication and the handling of fewer but larger units.

C. H. Newlin of the Southern Railway called attention (page 1073, 1955 Proceedings) to potential savings which can be obtained by designing to make use of the many special advantages of the material. With reference to a 45-ft bridge span with Cooper E 72 loading, he said:

"I believe we can obtain this timber span for about 60 percent of the cost of the steel span, in spite of the very high cost of glued laminated lumber."

The superior properties of structural glued laminated lumber have led to its extensive and rapidly increasing use in a large variety of structures including bridges, buildings

(Text continued on page 991)

Fig. 1—Glued laminated posts, caps and stringers in a Southern Railway trestle at Alexandria, Va. Note excellent condition after about 10 years of service.

Fig. 2—End view of glued laminated cap on the Southern Railway bridge at Alexandria.

Fig. 3—Glued laminated stringers in a Texas & Pacific Railroad trestle in Texas. Note excellent condition after about eleven years of service.

Fig. 4—Glued laminated, creosoted lumber arches in Culp Creek bridge designed for both railway and highway use. Cooper E 50 and H 15 loadings, 16-ft roadway, 117-ft span, near Cottage Grove, Ore.

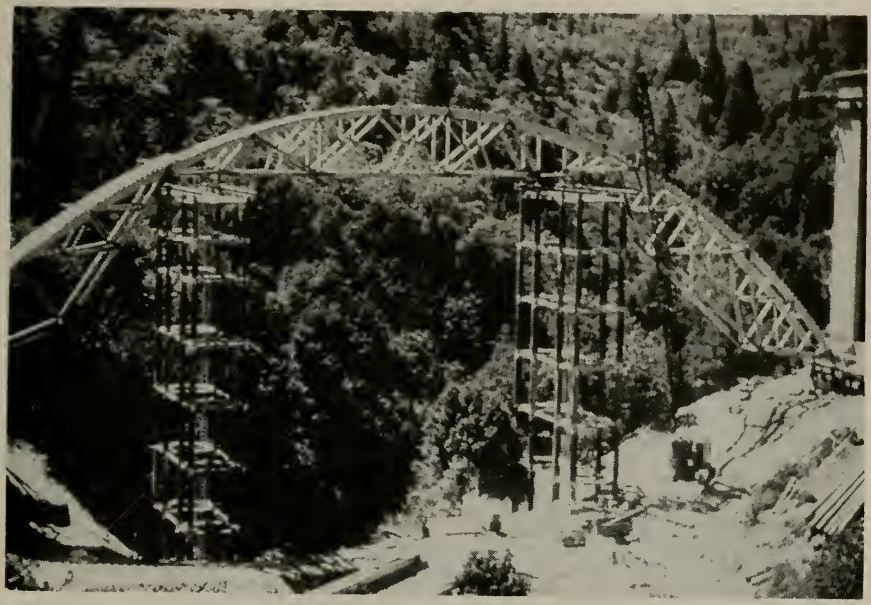


Fig. 5—Glued laminated lumber arch centering for 300-ft span concrete bridge near Shasta Lake, Calif.

Fig. 6—Note the efficient long-span design obtained by use of glued laminated beams and purlins continuous over two supports and cantilevered into adjacent spans to points of counterflexure, where simple beams are supported by the ends of the cantilevers. This equalizes the positive and negative moments, permitting use of smaller sections.

Fig. 7—Glued laminated lumber members serve the dual purpose of structural frame and interior aesthetic treatment.

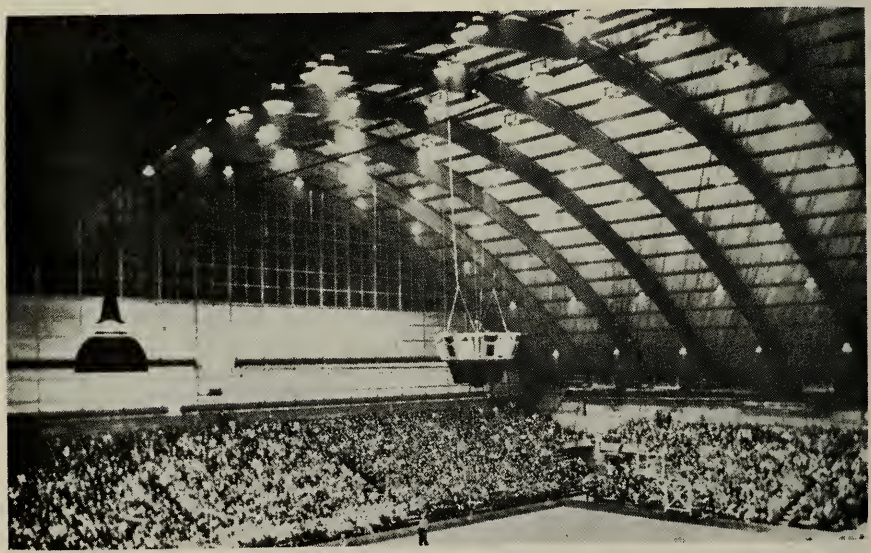


Fig. 8—201-ft 6-in span glued laminated, 3-hinge timber arches spaced 20 ft in Montana Field House seating 6500 people. Note simplicity of framing.

of all kinds, ships, waterfront structures, towers, etc. Buildings having glued laminated arches and trusses with clear spans of 250 ft and beams exceeding 100 ft have been built. Members having cross sections as large as 22 by 95 in have been used.

We suggest that you visit the AREA Committee 7 exhibit of full-scale sections of bridge stringers and caps and of photographs showing a number of railroad applications. It is located in the foyer outside this room just across from the registration desk.

Figs. 1 to 8 illustrate some forms taken by structural glued laminated lumber.

In line with the current railroad policy of seeking more aggressively a greater share of the transportation business through efficient service, modernization of facilities and better public relations, the use of structural glued laminated lumber for passenger and freight handling buildings, bridges and other structures is ideal. Its outstanding utility, economy and aesthetic qualities please all concerned. It has a "business-come-here" appeal. The architectural magazines are full of prize-winning designs using the product.

In conclusion, I urge each of you to become fully familiar with glued laminated lumber and to investigate practical applications for it on your own railroad. Your efforts will pay real dividends.

If the American Institute of Timber Construction or its members, who specialize in the design, fabrication and erection of engineered timber construction of all kinds and who manufacture the bulk of the structural glued laminated lumber produced in this country, can be of assistance, please inform us.

Vice Chairman Goldberg: Thank you, Mr. Hanrahan.

This concludes our special features.

I would again like to thank Mr. Hanrahan and Mr. Freas for coming here and addressing us this morning.

This concludes the report of Committee 7.

President O'Rourke: Thank you, Mr. Goldberg, and Mr. Schneider for a very interesting convention presentation by your committee, and thank you, Mr. Freas and Mr. Hanrahan, for your interesting presentations with respect to the development of working stresses and the application of such stresses in glued, laminated lumber. It is well that we keep abreast of this important development in the lumber and lumber fabricating industry.

Mr. Goldberg, your committee is now excused with the thanks of the Association. [Applause]

We will next hear from our Committee 28—Clearances, the chairman of which is Mr. A. M. Weston, senior assistant engineer, Baltimore & Ohio Railroad, at Baltimore, Md.

Mr. Weston, I shall be pleased if you and the other members of your committee would come to the platform at this time to present your report.

Discussion on Clearances

[For report, see pp. 547–551.]

[President G. M. O'Rourke presiding.]

Chairman A. M. Weston (B&O): Mr. President, members of the Association and guests: Committee 28 has seven assigned subjects, and the report may be found in Bulletin 526, pages 547 to 551. Our first report will be on Assignment 4, and will be presented by Subcommittee Chairman E. R. Word, special engineer, Illinois Central.

Assignment 4—Compilation of the Railroad Clearance Requirements of the Various States, was presented by Subcommittee Chairman E. R. Word (Illinois Central).

MR. WORD: Mr. President, members of the Association and guests: Your committee submits as information a tabulation of the clearance requirements of the various states, brought up to date as of December 2, 1955.

It has been customary in the past to revise this tabulation every other year. However, the committee felt that the statement showing clearance requirements should be published this year as 10 or 12 percent of the states have new regulations or made changes during 1955.

In those years when changes in the tabulations are few, the revisions will be covered in a written report.

CHAIRMAN WESTON: A progress report on Assignment 5 will be presented by Subcommittee Chairman S. M. Dahl, assistant division engineer of the Milwaukee Road.

Assignment 5—Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection, Collaborating with the Mechanical Division, AAR, was presented by Subcommittee Chairman S. M. Dahl (Milwaukee Road).

MR. DAHL: Mr. President and gentlemen: The report of your subcommittee this year is concerned with the effect of track and equipment irregularities on the action of equipment from a clearance standpoint. It is a progress report, submitted as information, and the subject is being continued.

During the past year the AAR research staff, in cooperation with the Lackawanna Railroad, conducted field tests on equipment similar to previous tests on passenger equipment on similar railroads. Two gondola cars, one with short-travel springs and one with long-travel springs, were loaded with rails to provide centers of gravity at 70, 85 and 100 in above the top of the rail. The analysis of the results of these tests has not been completed.

CHAIRMAN WESTON: Mr. President, this concludes the report of Committee 28, and also concludes my term as chairman. At this time I would like to present Mr. E. R. Word, special engineer of the Illinois Central Railroad, who will succeed me as chairman.

Also, I'd like to present again Mr. S. M. Dahl, who will succeed Mr. Word as vice chairman. [Applause]

PRESIDENT O'ROURKE: Thank you, Mr. Weston. The matter of railroad clearances for cars, loadings and personnel is one of great importance to the railroads. We are all interested in providing adequate operational clearances, but as your committee readily recognizes, there are definite practical and economic considerations involved which certain agencies and legislative and regulatory bodies sometimes fail to take into consideration.

I want to thank you, Mr. Weston, for your service to the committee and the Association as chairman of Committee 28 for the past three years, and to welcome Mr. Word as the new chairman and Mr. Dahl as the new vice chairman. I am sure that the work of your committee will go forward under their direction.

Your committee is now excused with the thanks of the Association. [Applause]

Continuing our consideration of structural matters, we will next hear from our Committee 30—Impact and Bridge Stresses. The chairman of this committee is Mr. E. S. Birkenwald, engineer of bridges, Western Lines, Southern Railway System, at Cincinnati, Ohio. Mr. Birkenwald, will you and the members of your committee please come to the platform and present your report?

Discussion on Impact and Bridge Stresses

[For report, see pp. 433–435.]

[President G. M. O'Rourke presiding.]

Chairman E. S. Birkenwald (Southern): Mr. President, members and guests: Six of 10 committee assignments are reported on in Bulletin 526, and will be presented as information. Three of the 6 reports are based on tests on 10 plate girder spans on the Milwaukee Road, published in Bulletin 523 in advance of the committee's annual report.

M. J. Plumb, of Plumb, Tuckett and Pikarsky, consulting engineers, Gary, Ind., will give the reports on Assignments 2, 3, 8 and 10.

Assignment 2—Steel Girder Spans with Open Decks and with Ballasted Decks;

Assignment 3—Dynamic Shear in Girder and Truss Spans;

Assignment 8—Steel Truss Spans with Open Decks and with Ballasted Decks;

Assignment 10—Stresses in Lateral Bracing of Bridges; were presented by Subcommittee Chairman M. J. Plumb (Plumb, Tuckett and Pikarsky, Gary, Ind.)

Mr. Plumb: Mr. President, members and guests of the Association: The Subcommittee on Steel Structures of Committee 30 reports progress on four assignments. Information on Assignment 2—Steel Girder Spans with Open Decks and with Ballasted Decks; on Assignment 3—Dynamic Shear in Girder and Truss Spans; and on Assignment 10—Stresses in Lateral Bracing of Bridges, is contained in two reports. We have been concentrating on our program of testing girder spans. Ten spans on the Milwaukee Road were the subject of a report published in Bulletin 523 and five spans on the Santa Fe will be included in a report scheduled for publication this summer.

Our present program of testing girder spans will be complete next year when we finish work on 10 spans on the Burlington Railroad. At that time we will write a summary report on all 35 spans.

We are proud to present in a forthcoming Bulletin a paper by Professor James Michalos of our committee, and Mr. J. M. Louw of the South African Railways. This paper offers a method of including the effect of gusset plates on secondary bending stresses in trusses. In those cases where it is considered advisable to calculate secondary stresses, the small amount of extra work involved in using this method will yield results much more accurate than if the effect of gussets is neglected. This is part of our report on Assignment 8—Steel Truss Spans with Open Decks and with Ballasted Decks.

Tests were made last year on a Scherzer bascule bridge at the request and expense of the railroad involved. This is the first time we have had field measurements of actual stresses in this type of movable bridge.

These are progress reports, presented as information.

Chairman Birkenwald: Report on Assignment 5 will be presented by Subcommittee Chairman J. H. Shieber, assistant engineer, structures, Missouri Pacific.

Assignment 5—Concrete Structures, Collaborating with Committee 8, was presented by Subcommittee Chairman J. H. Shieber (Missouri Pacific).

Mr. Shieber: Mr. President, members of the American Railway Engineering Association and guests: Of interest to the Association are the following facts obtained from the field tests of prestressed, pretensioned and conventionally designed railroad slabs in the Burlington Railroad bridge near Hunnewell, Mo.;

1. Prestressed slabs, after one year in service, show a slightly increased camber, thus indicating no loss of bond in the prestressed strands.
2. Observation of oscillographs taken indicate that there is good distribution of load across the prestressed slabs.
3. In both the prestressed and regular slabs, considerable vibration developed with only 2 in of ballast between slabs and cross ties. Even with the track across the bridge retamped, the same vibration characterisitcs were present. It appears obvious that such vibration can be eliminated with a sufficiently increased depth of ballast.

These facts are based on a partial study of data obtained. In all likelihood additional facts will become evident and conclusions reached when the analysis of data and the report are completed.

CHAIRMAN BIRKENWALD: Report on Assignment 7 will be presented by Subcommittee Chairman C. V. Lund, assistant to chief engineer, Milwaukee Road.

Assignment 7—Stresses and Impacts in Timber Stringer Bridges, Collaborating with Committee 7, was presented by Subcommittee Chairman C. V. Lund (Milwaukee Road).

MR. LUND: Mr. President, members and guests: Analysis has not yet been made of the data taken in connection with tests conducted in 1954 and 1955 on the two Seaboard Air Line Railroad ballast-deck trestles reported in the Bulletin under this assignment. However, certain significant results were apparent during the course of the tests, as follows:

(1) Outside stringers located under the ballast timbers carried very little vertical load.

(2) Longitudinal traction and braking forces were carried largely by the rails. Gages placed on the piles registered little bending due to these forces. Likewise, pressure cells placed back of the dump bents recorded little pressure attributable to longitudinal forces.

A summary of all significant data will be included in the final report.

This is a report, presented as information.

PRESIDENT O'ROURKE: It will be so received, and thank you, sir.

CHAIRMAN BIRKENWALD: Thank you, Mr. Lund.

You have heard the report of the committee. Are there any questions from the floor? The committee and I shall be glad to answer any questions which we can.

Mr. President, this concludes my almost four years as chairman of Committee 30—Impact and Bridge Stresses. During this time many changes have taken place. While retirements have made some inroads on its overall experience, the committee has been enlarged and revitalized by younger members of the Association. By realinement of assignments and better balance of abilities in its membership, the committee is now in a better position to perform its tasks more efficiently.

I had hoped when I took over as chairman that reports could be completed of the many tests made by the research staff of the AAR, some going back as far as 1948, or possibly earlier. Optimistically, I outlined a program which would overcome this lag. Now, at the end of four years, I find that possibly only as much as one-third of this program has been accomplished.

Frankly, the bottleneck in the work of the committee is the lack of a sufficient research staff to prepare the reports, which the committee reviews, and from which its conclusions are drawn. It should be apparent that tests made, but not digested and analyzed, afford no relief to the pitfalls of poor or costly design, or permit savings which could be accomplished through the gained knowledge that certain conventional assumptions may be extremely conservative. I am sure that the incoming chairman, and, for that matter, the entire committee, will welcome any steps which the Association and the AAR may take to relieve this situation.

It has been a pleasant four years for me—made so by the cooperation and enthusiasm of the committee and the research staff of the AAR, whom I thank in all sincerity.

At this time, may I introduce your new chairman and vice chairman. Your new chairman is D. S. Bechly, assistant to bridge engineer, Illinois Central Railroad, who is one of the most capable members of the committee.

Your new vice chairman is D. W. Musser, designer, Erie Railroad, who should afford Mr. Bechly the assistance which he will need.

Mr. President, this concludes the report of the committee.

PRESIDENT O'ROURKE: Mr. Birkenwald, you were present at the dinner Monday night when Mr. T. A. Blair, chief engineer of the Santa Fe System, made a splendid series of comments and recommendations for the future work of the research engineers who are now employed at the AAR Research Center on the campus of the Illinois Institute of Technology.

As you all know, we are going to have a groundbreaking ceremony Thursday afternoon for a new engineering laboratory building at the Center, and we hope that in the near future there will be an increase in personnel at the Center which will overcome those things that you mentioned in your comments.

Mr. Birkenwald, your committee continues to carry on many important investigations and tests, which have had a significant effect on bridge design and more economical construction and maintenance. We greatly appreciate the interest and enthusiasm with which you have directed the work of your committee for the past nearly four years, and wish to extend to you our sincere thanks.

We welcome Mr. Bechly as the new chairman of Committee 30, and Mr. Musser as the new vice chairman. I am sure that your feeling about Mr. Bechly's ability to handle your committee in the future is not overstated. We feel assured that the work of the committee for the next three years will be in good hands.

Your committee is now excused with the thanks of the Association.

I believe I see Mr. A. T. Vakili out there in the audience. Will you stand, sir?

This gentleman is chief maintenance officer of the Iranian State Railways. He was educated here in the United States. He was here from 1927 to 1933. He attended Tri-State College at Angola, Ind., and received his C. E. degree at Michigan College of Mines, taking postgraduate work at Purdue.

Mr. Vakili, we tried to introduce you yesterday, but you were not present. I'm glad to see you now, and hope that you are enjoying and will profit by attendance at our convention. [Applause]

We will now hear the report of our Committee 8—Masonry, of which M. S. Norris, regional engineer, Baltimore & Ohio Railroad, Pittsburgh, Pa., is chairman. I should be glad if Mr. Norris and members of his committee will come to the platform.

Discussion on Masonry

[For report, see pp. 529–545.]

[President G. M. O'Rourke presiding.]

Chairman M. S. Norris (B&O): Mr. President, members of the AREA and guests: The report of Committee 8—Masonry, will be found in Bulletin 526, pages 529 to 545, incl. The report includes a memoir in honor of Theodore Lincoln Condron, who died April 12, 1955. Mr. Condron was a Charter Member of the Association, a Member Emeritus of Committee 8, and contributed outstanding service to this committee for 35 years.

The report on Assignment 2—Principles of Design of Masonry Structures, will be presented by Subcommittee Chairman R. L. Mays, assistant chief engineer of the New York, Chicago & St. Louis Railroad.

Assignment 2—Principles of Design of Masonry Structures, Including Design of Masonry Culverts, Collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30, was presented by Subcommittee Chairman R. L. Mays (Nickel Plate).

Mr. Mays: Mr. President, members of the Association and guests: I wish first to refer you to the article "Attention Concrete Designers", appearing on page 11 of the AREA News, March 1956, which states that failures occurred in the reinforced concrete of United States Air Force warehouses, and that as a result of these failures Committee 318 of the American Concrete Institute proposes that certain changes be made in the ACI Building Code.

The AREA specifications for Design of Plain and Reinforced Concrete Members, in the Manual, Chapter 8, Part 2, are essentially the same as the ACI Code with respect to shear and diagonal tension, and in view of the action taken by the ACI in revising the code, Committee 8 will review the shear and diagonal tension requirements in the Manual and make recommendations for necessary revisions in March 1957.

In the meantime, designers using the Manual are cautioned to keep in mind the ACI code revisions for shear and diagonal tension.

I wish also to call your attention to a typographical error in Equation 18 appearing on page 8–2–19 of the Manual. The equation should be corrected to read:

$$P' = P\,(1.3 - 0.03\,\frac{h}{d})$$

The *"d"* in this equation was omitted during the 1953 reprinting of the Manual. It appeared correctly in the previous edition.

Your committee requests that a corrected page 8–2–19 be issued in the 1956 Manual Supplement.

Your committee has presented as information a tentative draft of Specifications for Design and Construction of Reinforced Concrete Box Culverts. There is a real need for such a specification in the Manual. Many railroads have their own specifications governing the design and construction of box culverts, but it is the thought that a specification placed in the Manual would help standardize practices and offer help in problems of design and construction which arise between railroads and contractors, and to set out minimum requirements when a railroad becomes involved in construction of box culverts at the expense and for the benefit of other parties.

This specification covers all important features of design and construction and also provides a typical plan for a 6-ft by 6-ft reinforced concrete box, and a typical plan for

a double 8-ft by 6-ft reinforced concrete box upon which ruling dimensions and sizes of bars can be placed for various lengths of boxes and various heights of fill. These typical plans can be used as a guide for the preparation of similar plans for all other sizes of boxes.

Several railroads now use typical plans for box culverts, filling in the ruling dimensions and sizes of bars as conditions require, with a considerable saving of time in the preparation of working drawings. This is an important item when engineering personnel is limited.

In the preparation of these specifications, I wish to acknowledge the great amount of work done by E. J. Ruble and other members of the AAR research staff.

These specifications are presented as information, with an invitation for your comments and criticisms before they are again presented at this time next year for approval and publication in the Manual.

PRESIDENT O'ROURKE: Thank you, sir.

MR. MAYS: This concludes the report on Assignment 2, but I should like to invite any discussion or questions concerning the report.

J. H. SHIEBER (Missouri Pacific): What effect, if any, will the proposed ACI revisions have on the design specifications for the design and construction of reinforced concrete box culverts?

MR. MAYS: Mr. Shieber, the committee believes there will be no effect on the design of reinforced concrete box culverts as a result of changes which the ACI has proposed. However, Committee 8 will review all of those things, and the proposed specifications before they are presented.

MR. SHIEBER: Thank you.

PRESIDENT O'ROURKE: Is there any further discussion of this important subject?

CHAIRMAN NORRIS: Thank you, Mr. Mays.

The report on Assignment 7—Methods for Improving the Quality of Concrete and Mortars, will be presented by Subcommittee Chairman R. A. Ullery, assistant to chief engineer, Bessemer & Lake Erie Railroad.

Assignment 7—Methods For Improving the Quality of Concrete and Mortars, Collaborating with Committee 6, was presented by Subcommittee Chairman R. A. Ullery (B&LE)

MR. ULLERY: Mr. President, members: Your committee presents as information a bibliography on admixtures for concrete. It is the intent of this report to aid the railroad engineer in understanding the use of admixtures and to provide a ready list of references on this subject.

From the numerous references available, 44 have been selected by the committee as most pertinent. These have been grouped into classifications based on the prime function of the admixture, such as air-entrainment, accelerators, retarders, waterproofers, etc., and a general subdivision under which articles explaining the function, justification for use of admixtures, etc., have been listed.

As published in Bulletin 526, the wording of the last sentence of the second paragraph on page 539 is not exactly as the committee intended, and it is requested that the words "following bibliography" be changed to "general subdivision". With this revision, your committee submits this report as information.

PRESIDENT O'ROURKE: It will be so received, sir; thank you.

CHAIRMAN NORRIS: Thank you, Mr. Ullery.

The report of this committee has been shortened to permit the presentation of a special feature by Committees 8 and 15.

Mr. President, this concludes the report of Committee 8.

PRESIDENT O'ROURKE: Thank you very much, Mr. Norris, and your committee, for the work that you have carried out during the past year. You are now excused with the thanks of the Association. [Applause]

Continuing the consideration of our structural subjects, we will next hear from our Committee 15—Iron and Steel Structures, of which Mr. A. R. Harris, engineer of bridges, Chicago & North Western System, is chairman. Mr. Harris, will you and members of your committee please come to the platform promptly and make your presentation?

We are now 30 min behind schedule, and I wish you would consider postponing your special feature until 2:30 this afternoon.

Discussion on Iron and Steel Structures

[For report, see pp. 553–564.]

[President G. M. O'Rourke presiding.]

CHAIRMAN A. R. HARRIS (Chicago & North Western): Mr. President, members and guests: The report of Committee 15 will be found on pages 554 to 564, incl., of Bulletin 527.

After presentation of our subcommittee reports, we will adjourn for the Annual Luncheon, and then, as a joint feature of Committees 8 and 15, there will be a slide presentation of structural damage by Hurricane Diane, with commentaries by W. R. Wilson, past chairman of Committee 8.

The report of Subcommittee 1, concerning Manual changes, will be submitted by E. S. Birkenwald, engineer of bridges, Southern Railway, Cincinnati, Ohio.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman E. S. Birkenwald (Southern).

MR. BIRKENWALD: Mr. President, members of the Association: Your committee, this year, is submitting for adoption and publication in the Manual, revisions to the Specifications for Steel Railway Bridges, the Specifications for Movable Bridges, and the Specifications for Erection of Steel Railway Bridges.

Many of the changes are editorial in character, in order to clarify the intent of the specifications. The two revisions to Art. 3 (a), Sec. A of the Specifications for Steel Railway Bridges will make the specifications consistent with modern practice in regard to the preparation of drawings and will insure receipt by the railroads of legible tracings of the drawings, in good condition, upon completion of the contract. Revision of Art. 11, Sec. A, was deemed advisable to permit adjustment in the distance from top of rail to top of tie for those rail sections used at variance with the usual practice of the majority of railroads. Since ties on bridges are referred to as bridge ties rather than cross ties, the revision of Art. 15, Sec. A, is accordingly in order. The revision of Art. 29, Sec. A, is required to eliminate a typographical error. It is felt that revision of Art. 76, Sec. A, should be made for clarification. The revisions to the Specifications for Movable Railway Bridges are to eliminate typographical errors.

The balance of the revisions are modifications of the specifications and were favorably balloted on. Revision of Art. 49, Sec. A, is necessitated by the need to limit the distance from the free edge of an outside plate or shape when thick cover plates are used

on heavy wide-flange beams. Revision of the third paragraph of Art. 61, Sec. A, permits the use of cover-plated beams as girders not heretofore provided; requires additional length of cover plates in accordance with research findings; and limits the percentage of gross area of cover plates in the total flange, consistent with modern practice. Revision of Art. 67, Sec. A, is necessary for appearance to permit in underpass construction the use of stiffeners only on one side of the plate girder. Revision of Art. 121, Sec. A, and that for the Specifications for the Erection of Steel Railway Bridges, are essential to conform to present-day practices, toward which your committee and the Association of American Railroads have contributed time, study and money.

Mr. President, I move that all of these revisions set forth on pages 554 and 555, Bulletin 527, be adopted and published in the Manual, and that the three revised specifications be reapproved.

[The motion was regularly seconded.]

PRESIDENT O'ROURKE: You have heard the motion, gentlemen. Have you any discussion? Are you ready for the question?

[The motion was put to a vote, and carried.]

PRESIDENT O'ROURKE: It is so ordered.

CHAIRMAN HARRIS: Mr. C. H. Sandberg, assistant bridge engineer system, Santa Fe, will give the report for Subcommittee 4—Stress Distribution in Bridge Frames.

Assignment 4—Stress Distribution in Bridge Frames, (a) Floorbeam Hangers; (c) Model Railway Truss Bridge, was presented by Subcommittee Chairman C. H. Sandberg (Santa Fe).

MR. SANDBERG: Mr. President, members and guests: During the past year the work of this subcommittee has been concerned primarily with making arrangements and getting under way our new research project on a model railway truss bridge. We have now progressed to the point where the steel has been ordered and the foundations are being constructed.

We had a fine turnout on the inspection trip to the bridge site on Tuesday afternoon. The project is being handled at Northwestern University Technological Institute, under the able direction of Professor Wyly.

This project is being sponsored by several organizations, the AAR being one of the main sponsors. We hope to have this large railroad bridge under construction some time next year.

This report is offered as information.

PRESIDENT O'ROURKE: Thank you, Mr. Sandberg. It will be so received.

CHAIRMAN HARRIS: The report on the preparation and painting of steel surfaces will be presented by R. C. Baker, engineer of structures of the Chicago & Eastern Illinois Railroad.

Assignment 6—Preparation and Painting of Steel Surfaces was presented by Subcommittee Chairman R. C. Baker (C&EI).

MR. BAKER: Mr. President, members and guests: The progress report of this Subcommittee calls to your attention certain paint tests planned by this committee, cooperating with the Steel Structures Painting Council.

The application of the test paints on The Seaboard Air Line brine drippings paint test was completed this past year.

The Pennsylvania Railroad weathering versus shop painting test remains in the planning stage as the railroad company has not completed its plans for this structure. It is hoped that tests of this same type can be performed at other geographical locations and on different types of structures.

With respect to the Missouri Pacific brine drippings paint test, present plans call for an inspection to be made early this year and for a progress report to be issued on this test.

As to the future research program of the Council, the Steel Structures Painting Council is and has been conducting an extensive program of research aimed at making the painting of steel better and more economical. This program includes the cooperative field paint testing program; Council field paint tests; the low cost shop paint test; tests for paints to use over rusty steel and over mill scale; best methods of painting over welds to prevent paint failures over welds; and considerable evaluation of the latest developments in new paints, methods of application and corrosion protection.

The results of this research program are available to the entire railroad industry. Suggestions and constructive criticism from you will help to insure the success of this program.

PRESIDENT O'ROURKE: Is there any comment? Are there any suggestions or criticisms from the floor? If not, we will receive the report as information, and you may proceed, Mr. Harris.

Assignment 10—Substitutes for Paints for Preservation of Steel Bridge Structures.

CHAIRMAN HARRIS: The report on this assignment will be found on page 557. Mr. Ekberg, chairman, is not present today. I would like to comment that the full committee voted to discontinue this subcommittee. However, Subcommittee 6 will, nevertheless, include some of the asphalt oils and similar compounds in their tests of the bridges under way, and if anything does show up on some of these substitutes, we will get full information on that.

Assignment 11—Economics of Various Design Loadings.

CHAIRMAN HARRIS: This report was to have been presented by E. E. Burch, chairman of the subcommittee. I understood he would be here this morning, but apparently he is not here. We don't have anyone else here who, I think, would be prepared to offer any comment at this time, on such short notice, but I believe that report is very complete and self-explanatory.

Before offering it for information, however, I would be glad if anyone in the audience would care to offer any discussion concerning this report.

MR. BIRKENWALD: May I say something? I believe the report warrants at least one comment, and that is that when it comes to the designing of the steel for a bridge, whether you take E 50, E 60 or E 72, the effect of the capacity of the bridge for which you design affects the economy of the bridge in a very small way. This report bears this out, and it would be well for all of you to thoroughly study it. I think it is a good report. I think it certainly warrants calling attention to the fact that no matter what the design of your bridge is—that is, the steel portion of the bridge—the percentage of increase in cost because of the increase in capacity is very, very small.

PRESIDENT O'ROURKE: Thank you, Mr. Birkenwald.

Proceed, Mr. Harris.

CHAIRMAN HARRIS: That concludes the report of Committee 15, except as to the special feature—the slide presentation—which, as I stated earlier, will be deferred until after luncheon. I understand that the luncheon will proceed on schedule.

PRESIDENT O'ROURKE: That's right.

CHAIRMAN HARRIS: So I request that all those present, if possible, return to this room immediately after the luncheon, when all members of Committee 15 will reassemble at the platform here for this presentation.

PRESIDENT O'ROURKE: Thank you, Mr. Harris, and your committee, for your work for another year. We look to your committee to keep its important Manual documents up to date and to add to them as conditions require, and it is evident that your committee is alert to this responsibility.

Mr. Harris, we particularly appreciate your accepting the chairmanship of Committee 15 in "midstream," as it were, between conventions, when the office was vacated last June, and I congratulate you upon the aggressive way you have taken hold of and progressed the committee's work.

At my request, Mr. Harris has postponed the special feature, the pictures, because I thought if we didn't do this, we wouldn't do justice to the presentation. Another reason is because our principal speaker, Mr. Johnston, must be released at 1:45, and no later, because he has an important engagement this afternoon. Therefore, I appreciate your postponing this special presentation until 2:30 this afternoon.

Your committee is excused for the present.

This completes our morning session, but before I recess the meeting for the luncheon, which is to be held in the Grand Ballroom, I would again like to remind you of the ground-breaking ceremony for the new AAR engineering research building at the AAR Research Center, Thursday afternoon.

We will reconvene at 2:30 pm.

[The meeting recessed at 11:45 o'clock.]

Annual Luncheon

Grand Ballroom, 12:00 m

Wednesday, March 14, 1956

The Annual Luncheon was held in the Grand Ballroom to the background of music by a string trio. As the Luncheon started, the president's wife and 27 guests were escorted to a table in the center of the room. Immediately thereafter the chairmen of all the Association's standing and special committees were escorted to a speakers' table directly in front of the main speakers' table, and their entry was followed by a procession of 20 officers, past presidents of the Association and chief executive officers of the railroads who were seated at the main speakers' table. The total attendance at the Luncheon was 1205.

Beginning the after-Luncheon functions, those assembled sang the National Anthem, following which President O'Rourke introduced those at the speakers' tables, after which he recognized those at the president's wife's table. In doing the latter, he said:

"Last, but certainly not least, I would recognize the table directly in front of me, seated at which are the wives of quite a number of our officers, past presidents and other guests. You ladies add a dash of color to what would otherwise be a rather drab-looking affair, and I am especially pleased to detect a bit of green in your table decorations, Bells of Ireland on the table and a Belle of Ireland at the head of the table. Now, I ask you, what could be more lovely?" [Applause]

President O'Rourke then introduced the speaker at the Luncheon, Wayne A. Johnston, president, Illinois Central, with the following remarks:

PRESIDENT O'ROURKE: I must now turn hurriedly to the main feature of our Luncheon program. One of the most pleasant duties that I have been called upon to perform

as your President is the one which is now mine in presenting the speaker for this 55th Annual Luncheon of the American Railway Engineering Association.

It has been our custom in the past in selecting a speaker for this occasion, in almost every instance, to invite a man from our own railroad industry. We have been unusually fortunate in having fine messages from our railroad executives heretofore and, knowing the man who is here today as well as I do, I am sure that he will bring us a message to take home and think about for a long time.

He is a man of ideas, an ingredient along with the dynamic attributes of industry, integrity, personal efficiency and discipline that have carried him to the top.

He meets, head on, the challenge to railroad executives that exists today, more than ever before, and with extraordinary vitality of body and mind keeps up to date on new developments and trends.

This is such a great pleasure for me—not only because our speaker is the chief executive officer of the railroad with which I have the privilege of being associated—but also, and even more particularly, because his shining record as a smart railroader and a stimulating leader, as a conscientious citizen and as a true Christian gentleman lends particular weight and emphasis to the message which he brings to us on this occasion at the climax of our AREA year.

I do not need to review our speaker's railroad career to such an audience as this. Let me simply remind you that he started to work for the Illinois Central in 1919 following his graduation from the University of Illinois; that his experience along the line that led to his present position covered nearly every phase of railroad operation; and that during the eleven years of his presidency, the Illinois Central has reflected the inspiration and enthusiasm of his gifted leadership. The great industry to which we all have dedicated our working lives has no more articulate and challenging spokesman.

Our speaker is a busy man, and much as he was delighted to accept my invitation to address us, he did so several months ago only with the understanding that he could be released at 1:45 o'clock sharp in order to keep another engagement. So, we made the deal, and since he is my "big boss", it is essential that I keep my part of the deal if I want to stay around here.

It is with the greatest pleasure and genuine pride that I present to you as our speaker today the president of the Illinois Central Railroad, who will address us on "The Ever-New Challenge of Railway Engineering"—Mr. Wayne A. Johnston.

The Ever-New Challenge of Railway Engineering

By Wayne A. Johnston
President, Illinois Central Railroad

Gentlemen, in my decade of service as president of the Illinois Central, I have been before quite a few large audiences. I don't believe, however, that I have appeared before any larger than this one, or any that gave me as great a pleasure to address. This is indeed an impressive audience. Here you are gathered from all over the North American continent, the men who build and maintain the tremendous network of tracks and facilities which bind our states and our countries together. I am greatly pleased to be here, because I feel that through me you honor your president, and that gives me genuine pleasure.

You made no mistake when you elected George O'Rourke your president, But, of course, I don't have to tell you that. His reputation does not need any embellishment from me. Let me tell you something about him, because all of you may not know him as well as I do. George began his career in the purchasing department, but soon transferred to maintenance of way. There he felt the inspiration to become an engineer, and he enrolled for night courses at Armour Institute, which today is the Illinois Institute of Technology. In 1951, George had a most interesting assignment with the Economic Cooperation Administration in making a survey of West German railroads. Later he conducted a study of transportation facilities in New York. He is the prototype of the good engineer—good formal training, excellent practical experience, years of knowledge, and with it all—the open mind that marks a man young in spirit, no matter what his years. He is a gold-pass veteran, which means that he has a half century of service in our ranks. You could have paid the Illinois Central no higher compliment than to have chosen George O'Rourke your leader. I am confident he has given you a good administration

Just as were my predecessors, I am a firm believer in association work. I always feel that when the right man is selected, the company and the man alike gain by his membership. The railroad that recognizes the value of participation in the affairs of a good association is a wise railroad. Yes, it takes company time and money to support an officer in his association work, but it is time and money that earns a good return.

We have been extremely fortunate on the Illniois Central in having had the kind of men you have elected to leadership. As you probably all know, the very first man to handle the gavel in this association was John F. Wallace in 1899. A few years later Wallace's reputation was such that he was named chief engineer in the construction of the Panama Canal. Another Illinois Central man was A. S. Baldwin, who was chief engineer when this association selected him as president. Then one of my predecessors on the job I now hold, Larry A. Downs, was once your president. As assistant engineer of maintenance of way on the Illinois Central, and later as an operating officer, Mr. Downs showed such ability that he was made president, first of the Central of Georgia and then of the Illinois Central. It was his unenviable task to save the railroad from bankruptcy in the grim days of the 'thirties, and by superhuman efforts he succeeded.

D. J. Brumley also had the honor of leading this group, elected to the post while chief engineer of Chicago Terminal Improvement, which brought about the electrification of our suburban system and the development of the south side of Chicago. Mr. Brumley has enjoyed a long retirement, and is a neighbor of mine in Flossmoor.

Then, of course, you had an Illinois Central man during your big Golden Anniversary year in 1949, Charles H. Mottier, and Charley still serves us with distinction as vice president and chief engineer. He has a reputation as a man who does big things. He has earned that reputation by such achievements as the Union Passenger Terminal at New Orleans, and the unique changeover of the bridge over the Ohio River at Cairo. His latest accomplishment is the beautiful Prudential Building on air rights over our tracks nearby. Before he retires, he may have one or two more major accomplishments to show for his years on the Illinois Central.

In addition to these half-dozen men who served AREA while working on the Illinois Central, there were others like L. C. Fritch, later vice president of the Rock Island Lines; George J. Ray, later vice president of the Lackawanna, and L. W. Baldwin, later president of the Missouri Pacific. All these men preceded George O'Rourke as president of AREA, and all either served their full careers or part of them on the Illinois Central.

I single out these leaders out of pride for their Illinois Central affiliations, and also to make the point that this organization has attracted top leadership throughout the years.

With your 3300 members from the United States, Canada and Mexico, and with your sprinkling of membership in other parts of the world, you wield a tremendous influence on the future of railway transportation. This association is beginning its 58th year of work in helping to build and maintain better railroads. All around the world, your members benefit from the work of your committees and the bulletins they issue. The AREA Manual of Recommended Practices is the bible of your profession. Yours is a democratic organization, and as in any true democracy, the ideas for progress come from within the group. The proceedings that are transpiring here during these three days will describe progress in railway engineering that will influence railroad planning and building everywhere.

That is the reason the work of your some two dozen committees is so important. I am told that one-third of your entire membership takes part in this committee work. A tremendous educational function is performed by these men. And as is so often true, those who teach learn more than those who are taught. The 1100 members who serve on these committees therefore are becoming better engineers as they help their fellow members.

As a non-engineer, I have always been fascinated by the way your predecessors built the pioneer railroads. On the Illinois Central, for example, it was Colonel Roswell B. Mason and a devoted band of young engineers who came out to the Illinois prairie to build the original railroad. Those engineers, some of them smooth-faced boys fresh out of Eastern schools, pushed the new railroad over rivers and hills, and through prairies, swamps and forests. There were manpower and material shortages. Contagious diseases sometime depopulated entire work camps. Often there were ugly fights among unruly workmen, serious clashes with native farmers. The means of transporting men and materials were slow. Picks, shovels and wheelbarrows were the principal tools used in grading. Ox and mule teams with slip scrapers helped speed the work.

The original 705-mile Illinois Central was the longest railroad in the world when it was completed. To get it finished on time, some work of a temporary nature had to be done. But the impressive thing is this: All the work had the earmarks of good workmanship. A few of the old stone and brick depots have been used right up to the present time. Except for reducing grades in recent years, there has been little need to relocate line. In other words, those engineers of more than a century ago planned well and built well. Their work helped to make Illinois a great farm state and eventually a great manufacturing state. In many towns and cities, streets and avenues are named for those original engineers, and it is right and fitting that they have been so recognized. The same kind of men, I am sure, helped to build the railroads represented in this room. They were the builders, and our debt to them is a deep one.

Now we come a century further along. Today the industry is considered an old industry. Except in countries with wild frontiers, no great new railroads are being built. And yet there is still a need for trained engineers in the railroad business.

Of course you would expect me to say that. Anyone knows trained engineers would be needed if only to maintain the track and the structures we already have. But engineers are needed for much more than merely holding on to what we have—important as that may be in terms of billions of dollars of investment. To conserve only what we have would be the mark of a declining industry. The future of the railroads is bright only

to the degree in which we move ahead. And we cannot move ahead without the skills and the imaginative leadership of the trained engineer.

There are some who gloomily foresee the end of transportation by rail in the years ahead, but I have no time for such pessimism. Nothing devised by the mind of man has ever exceeded the principle of the flanged wheel on the steel rail, moving along with a minimum of friction, moving great tonnages with maximum efficiency. I always note with interest that backward countries in the world always do two things to pull themselves out of the rut of poverty and backwardness. One, they teach their people to read, and two, they start to build railroads.

I do not pretend to have a crystal ball that reveals the nature of railroading of the future. But we all know there has been an almost complete transformation in motive power on American railroads since the end of World War II. That transformation has affected all phases of railroad operations. Now we are entering upon a new era in railroading—experimentation with various methods of moving freight loaded in trailers on flat cars. With the prospect for something like 80 million vehicle on the highways in another decade, there is every reason to believe that much of the tonnage now moving by truck can be brought off the highways and back to rail.

Where does the trained engineer fit into this picture? Practically everywhere, it seems to me. He has the scholastic background, the technical competence, to meet and solve a wide variety of railroad problems.

Take the problems involved in the trend toward lightweight equipment. At the moment there are four different types of experimental trains rolling around the United States. I don't suppose any of the builders believe they have the final answer to the need for a fast, safe, comfortable ride at an economical price. The fact is, part of that final answer will have to come from men in your ranks. Lightweight equipment can't be bounced around. If it is, the bumpy ride will chase customers away. George O'Rourke tells me that European engineers criticize our track structure. They say that it is not good enough for their trains. Our streamline equipment with its spring arrangement and snubbers, with articulated couplings and other devices, eliminates the discomfort that otherwise might be caused by our standards for trackwork. But if lightweight equipment of the type used by European railroads should prove to be practical for widespread use, we may need to change our thinking about line and surface.

In all likelihood higher speeds will call for line changes to reduce curvature. Perhaps the answer to improved running time between cities is not simply higher top speeds, but longer runs at sustained speeds—not at 20 miles and then at a 100, but at a steady 80. Whatever the answers, the engineer will be involved in the final decisions.

The flood of vehicles on the highways has brought increasing pressure upon the railroads to protect the motoring public. In some parts of the country, where there is a high percentage of motorists, the pressure is intense upon railroads to build grade separations. These projects are extremely costly. Negotiations between railroad representatives and those of state, national and local agencies call for expert knowledge and ability on the part of the railway engineer involved. More than engineering skill alone is needed if the railroads are to be well served.

In a short talk, I can only touch upon a few of the many fields in which the engineer of the future will be working. That engineer in some ways will have to be a better engineer than his father and his grandfather before him. He may not have to fight malarial swamps as his predecessors did. The wintry blasts may not be as cruel or the broiling sun as hot, because modern devices have lessened physical discomfort. But the engineer of the future will face problems of human relations far more complex than

those faced by his forerunners. The open prairie of a century ago has become a great sprawling city in which a tangled mass of deeds and legal documents make property changes a complicated business. Then, too, the competition in transportation is such that the engineer of the future will need more and more to have the skills of the businessman, the accountant, the public relations man. An operation that once was simply a battle against nature has now become a complex interweaving of elements of technology, law, business and human relations.

In other words, the day of the rough and ready engineer largely has gone. The new engineer will need the same qualities of self-reliance, of loyalty and dependability possessed by the engineer of the past, but in addition he will have to possess skills beyond sheer engineering. He will, for example, need to know how to handle men in a way that was not known (or at least not generally practiced) in the past. In this way of intense competition between companies, the difference in manpower is often the difference between success and failure. We know now that a man's production is influenced by psychological factors that once were little noticed.

Here in the United States, as indeed everywhere, our nation needs trained technical men. Your association is aware of the need of our railroads for such men, and indeed has worked toward obtaining them. Charles Mottier is a member of the committee which has been wrestling with this problem. I am acquainted with the excellent brochure that has been prepared by your Committee on Cooperative Relations with Universities. I highly approve of its stimulating content and of the wide distribution that has been made of it. As some of you may know, I am a trustee of the University of Illinois, where we produce some fine railroad engineers, and I know that this type of publication has been most helpful on that campus. It undoubtedly has at other schools, too.

My time is getting short, but I do at least want to touch upon the subject of research. Sometimes the railroads are accused of not spending enough for research by comparison with outside industry. I am pretty sure that is not true, but one fact is true: Railroads do not earn as high a return on their investment, and therefore do not have as much profit out of which to sponsor research. But fundamentally, the answer to this accusation is that railroad research cannot be measured in the same way as laboratory research in a particular company. For example, probably most of the men in this room are engaged in research. It has well been said that the American railroads are a quarter-of-a-million mile "proving ground." How does one put a price tag on the numerous experiments that take place each year under actual working conditions all over North America? The railroads do not measure the dollar value of these research projects, but unquestionably they serve a valuable research role.

Then, too, our railway appliance cousins work steadily at improving the products they offer for sale. The development of lightweight trains is an indication of the zeal for research shown by manufacturers. All of you are acquainted with the steady flow of new and improved tools for construction and maintenance work. Almost always these tools are perfected only after long periods of experimentation, of testing on the job, of alterations to meet specific railroad needs. I doubt that the appliance manufacturers have a figure that shows the amount of their combined research, but, again, we all know they do a great deal of research that is highly important to our progress.

The research carried on through the engineering division of the AAR is growing steadily. It was only a few years ago that the first research laboratory was established on the campus at the Illinois Institute of Technology. Then a second was built, and now, within a few days, a third is being started. It is my understanding that, except for projects sponsored by the mechanical section of the AAR, most of the research being

carried on at the Research Center is sponsored by committees of this Association. We in railway management know that our future is closely geared to the success of the research being carried on here on the South Side, as well as everywhere in the railway field.

All research, of course, has one goal—to help us find better ways of doing the job ahead. Since the end of World War II, railroads have been spending at the rate of a billion dollars a year to modernize and improve their plant. Even greater sums will be needed in the future. As I have said, we will need good engineers to help us determine how such future investments should be made so as to receive the greatest good from them.

When we talk about sums like a billion dollars a year, the question comes to mind: Where is the money coming from? We can't go to the public treasury and ask for help, as some of our competitors do. We have to earn our way—and that's the way we want to keep it, too.

This subject of earning our own way brings me to my last item. It is a subject worth a long and forceful talk. I will only mention it, but I want you to understand the great importance I attach to it.

I speak of the need for reform of transportation law. All of you have seen and heard a good deal about the transportation report issued by the White House and the bills that have been drawn in Congress. I cannot stress too strongly the importance of these bills. The whole future of railway transportation rides on their ultimate success. We cannot continue to exist as a successful industry if we remain shackled by laws drawn in horse-and-buggy days. In some quarters, I seem to sense a certain resignation to failure. Perhaps some feel that an election year is no time to get a favorable vote on a highly controversial bill. Others seem to despair of ever defeating the philosophy of government spending on subsidized transportation.

I can tell you this: Every railroad man should be fighting. On the Illinois Central we are foolish enough to think we are going to win. We know we face a long fight, but we can't hold back simply because the end of the battle may be far off.

If we can have the chains of outmoded regulation removed, so that we can compete freely like other elements in American business, we can win. Never forget—we have one tremendous asset. Railroads are the best buy. The only way our competitors can stay up with us is through government help. Therefore, we must fight like wildcats to have that help removed.

Here you are, more than a thousand strong. We need you. If you don't know the facts of the subject, get them from your companies. Talk to your friends, volunteer to speak at your service club, write letters, work, fight. We're in for the fight of our lives. The trucks and the waterways are fighting tooth and nail. Do we believe in our cause? Then we must fight, too. I hope every man here walks out with the determination that he is going to do his part. God bless you all.

President O'Rourke: Mr. Johnston, the personal tribute you paid to George O'Rourke, not as President of the American Railway Engineering Association, but as an old friend on the Illinois Central Railroad, is very much appreciated. I cannot remember when I did not want to do the work I have been permitted to do for the past half-century; that is, to be a maintenance engineer on the Illinois Central for such men as Wayne Johnston. It is a wonderful thing to be granted the privilege, as I have been, of doing the work you love to do for that length of time.

Everyone who heard your address will agree that I did not exaggerate when I said you had a message for us. It is highly gratifying to see the interest taken by our higher

executive officers in encouraging the younger technical men to join the American Railway Engineering Association and thus early in their experience gain the benefits to be derived through Association activity.

The enthusiastic applause for your address that has come from this audience leaves little for me to say. On behalf of the American Railway Engineering Association, I wish to thank you for taking time out of your busy schedule to address our Luncheon today. Knowing of your other pressing engagement, you are excused to leave presently or at any moment you desire, which will not interrupt in any way the simple, yet important further ceremony planned for this occasion.

President O'Rourke: I have already recognized the current chairmen of our standing and special committees at the table immediately before me, but I want to pay special tribute to eight of these men who, having completed their allotted three years as chairmen, will relinquish this high office with the close of this annual convention tomorrow. I hope that these men sense our deep debt of gratitude to them for the service which they have rendered to their respective committees and to this Association. While we will assuredly miss their hand on the throttle of committee work in the days ahead, we are fortunate, indeed, that, with their help, the Association has been grooming their successors. These successors happily are with us here today, as the guests of the Association, and are seated at the table immediately at the extreme right-hand end of the Speakers' Table.

As you know, in recent years, each new chairman has been presented with a chairman's gavel when he has assumed office. I hold one of these gavels in my hand. The gold headband bears the name of the man, the number of his committee, and the term of his office.

Deviating from the previous practice of making these presentations at the time of the report presentations of the committees involved, we have planned to make all of the presentations at this time, in a simple ceremony in which the retiring chairman will, in effect, transfer his gavel—the symbol of authority—to the incoming chairman. Therefore, as I read the name of each new chairman, may I ask that he proceed immediately to the retiring chairman of his committee, who will present him with a gavel.

The first man to receive a gavel is the incoming chairman of Committee 1—Roadway and Ballast, Mr. A. P. Crosley, engineer maintenance of way, Reading Company, Philadelphia, Pa.

The next man to receive a chairman's gavel is the incoming chairman of Committee 5—Track, Mr. W. E. Cornell, engineer of track, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

The next man to receive a gavel is the incoming chairman of Committee 9—Highways, Mr. C. I. Hartsell, division engineer, Chesapeake & Ohio Railway, Saginaw, Mich.

I now recognize the incoming chairman of Committee 11—Records and Accounts, Mr. Morton Friedman, chief valuation engineer, New York Central System, New York, who will receive his gavel from the retiring chairman of Committee 11.

The next man to receive a gavel is the incoming chairman of Committee 14, Mr. F. A. Hess, division engineer, Indiana Harbor Belt Railroad and Chicago River & Indiana Railroad, Hammond, Ind.

The new chairman of Committee 27 is Mr. A. W. Munt, supervisor of work equipment, Canadian Pacific Railway, Toronto, Ont., who will receive his gavel from the retiring chairman of Committee 27.

Mr. E. R. Word, special engineer, Illinois Central Railroad, is the new chairman of Committee 28—Clearances, and will receive his gavel from the retiring chairman of that committee.

Last, but not least, I present to you Mr. D. S. Bechly, assistant to engineer of bridges, Illinois Central Railroad, who is the incoming chairman of Committee 30—Impact and Bridge Stresses.

To all of you new committee chairmen, may I say "Congratulations", and that I wish you the greatest of success in the direction of your committee's work during the next three years.

PRESIDENT O'ROURKE: There are two of our present committee chairmen, who, having assumed the office of chairman in "midstream" as it were, since the last convention, have not received chairman's gavels. I do not know how they have carried on committee work thus far without a gavel, but in order to rectify the situation immediately, I want to present them with a gavel at this time. Mr. A. R. Harris, engineer of bridges, Chicago & North Western System, who assumed the chairmanship of Committee 15—Iron and Steel Structures, on June 24, 1955. [President hands gavel to Mr. Harris.]

PRESIDENT O'ROURKE: The other chairman is Mr. C. E. Weller, division engineer, Illinois Central, at Jackson, Tenn., who assumed the chairmanship of our Special Committee on Continuous Welded Rail on July 12, 1955. [President hands gavel to Mr. Weller.]

PRESIDENT O'ROURKE: Our new officers will be installed at the business session of our convention beginning about noon tomorrow. You are all welcome to this session, and I hope that many of you will be there.

Before I dismiss the Annual Luncheon, may I ask that all of you remain in your places until the ladies have left the room. The Annual Meeting of our Association will be reconvened immediately in the Red Lacquer Room. We have a long and interesting program for the remainder of the afternoon, and I urge that you assemble promptly. The Annual Luncheon is now dismissed.

Afternoon Session—March 14, 1956

[The meeting reconvened at 2:35 pm, President O'Rourke presiding.]

PRESIDENT O'ROURKE: The meeting will please come to order.

I interrupted the presentation of the special joint feature of Committees 8 and 15 before lunch because I didn't want to rush through it. Mr. Wilson would have been under great pressure if he had attempted to present his pictures before lunch.

I shall now turn the microphone back to Mr. A. R. Harris, chairman of Committee 15, for the necessary introductions.

MR. HARRIS: It is with pleasure that I introduce Mr. W. R. Wilson, assistant engineer, Santa Fe, who has been selected to make the commentary for the slide presentation of the structural damage caused by Hurricane Diane. Mr. Wilson, as a former chairman of Committee 8, is not only familiar with masonry design, but is also familiar with structural steel design, and, accordingly, I don't think there is anyone who could better represent the two committees. Mr. Wilson.

W. R. WILSON (Santa Fe): Mr. President, gentlemen: In August of last year a hurricane was bred in the Caribbean. After circling around there for a while, it finally struck the United States in the Carolinas, and cut a wide swath to the north.

About August 18, the force of the hurricane had been expended, and it came to a rest over northern Pensnylvania, New York and the New England states. As it came to a rest, it dumped the tremendous load of water that it had picked up from the

Caribbean. The resulting floods caused about 200 deaths, and property damage estimated in the billions.

Much of that damage was done to railway roadbeds and bridges. Committees 8 and 15 have arranged a showing of a few selected pictures of this damage, with the thought that there might be lessons to learn from them, and that changes in our procedures might be indicated which would make our structures more resistant to this type of failure.

In viewing a large number of pictures, it was noted that many of the failed bridges crossed the streams on a skew, or the stream had a sharp bend just above the bridge, which caused the water to flow against an abutment, pier or approach fill. In discussing these failures with the engineers from the railroads affected, it was noted that the foundations were not well keyed into rock, and that those resting on material which would scour were the ones that failed. Many foundations with adequate pile supports, subjected to the same water pressure, stood up.

I would like to read just two short paragraphs from a letter recieved from Mr. A. E. Cawood, engineer of structures of the New Haven, which was one of the hardest hit railroads. He says: "It is interesting to note that of the half a hundred or so bridges that were destroyed due to the loss of our masonry substructures, only two or three of these structures were suported on piles. In our reconstruction of these bridges, we have, of course, used piles extensively, as well as the additional protection of steel sheathing.

"Many of our lines run parallel to streams and rivers that cross under our railroad at many points, and usually at severe angles. It was mainly at these points, where the rampaging rivers chose to continue on a more nearly straight path, that they caused

(Text continued on page 1015)

New Haven Bridge 61.31 at Putnam, Conn. Failure of west abutment, founded on gravel.

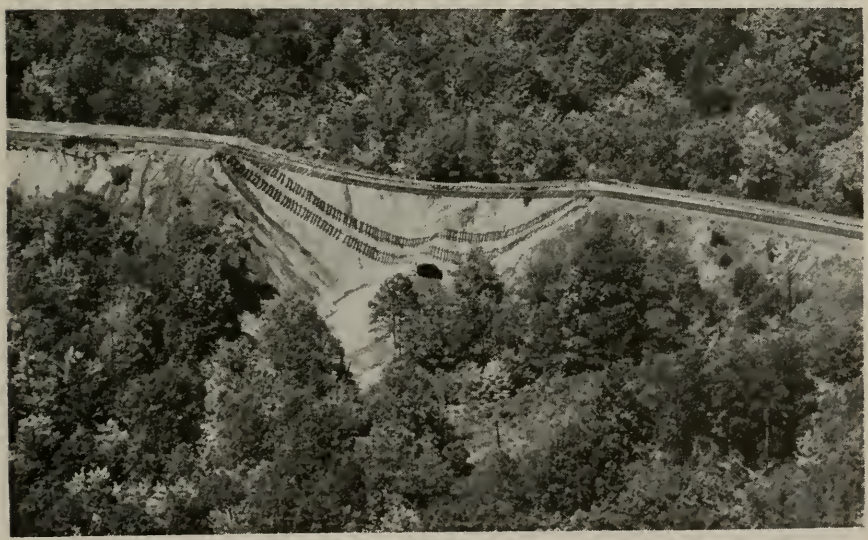
New Haven Bridge 14.92 at Georgetown, Conn. The stream approached the bridge at a skew toward the south abutment, which failed.

New Haven Bridge 19.27 at Waterbury, Conn. shows the effect of the stream striking against bank.

New Haven Bridge 32.25 at Farmington, Conn. This was a highway underpass. The river, ¼ mile away, diverted down the highway.

DL&W, Bells Bridge, girder spans across Brodhead Creek near Stroudsburg, Pa. Creek rose 30 ft in a matter of minutes.

DL&W concrete bridge at Analomink, Pa. Span still intact. Wing walls broken. Length of washout about 800 ft. Photo by Fairchild Aerial Surveys, Inc.



Devil's hole at Mt. Pocono on DL&W. Fill over 15-ft stone arch washed out 100 ft deep, 300 feet across. Photo by Fairchild Aerial Surveys, Inc.

20-ft stone arch culvert on the Erie at Parker's Glen, Pa., built about 1878; view looking downstream toward Delaware River. About ¾ of arch destroyed and 300 ft of embankment washed out. Fill over arch ring about 45 ft high. Arch destroyed by scouring action of water which probably washed out portions of embankment before washing out arch benchwall, permitting arch ring to collapse. Stream normally about 25 ft wide and 3 ft deep. During height of flood stream was 15 to 20 ft deep.

50-ft stone arch bridge on the Erie at Shohola, Pa., built about 1873; view looking downstream toward Delaware River. About 2/3 of arch destroyed. Distance from base of rail to stream bed about 80 ft. Arch destroyed by scouring action of water, cutting out west bench wall and permitting arch ring to collapse. Stream makes a sharp right angle turn just prior to entering opening under railroad at this location. Normal depth of water about 5 ft but during flood was about 25 ft deep.

View showing old stone "Tee" abutment discovered in fill at M. P. 105.79, Shohola, Pa., on the Erie, after washout of 50-ft stone arch. The Tee abutments were built about 1848 for single-track deck timber truss bridge. Masonry, consisting of blue stone and granite, was found to be in excellent condition. The Tee abutments were used to support a new 109-ft single-track deck plate-girder span.

such terrific damage to our bridges and roadbeds. The accumulation of debris, which washed down the valleys and piled against the bridges, created a dam effect, which was a serious blow to us, as many structures were lost for this reason."

If I may now have the slides, we will start with a few pictures of the New Haven Railroad's flood damage.

[Showing of slides depicting flood damage in aftermath of Hurricane Diane.]

Mr. Wilson: That completes the pictures we have of the flood damage caused by Hurricane Diane. [Applause]

Mr. Harris: Does anyone have a question he would like to ask Mr. Wilson concerning these slides? If not, I will thank Mr. Wilson for his very constructive presentation.

I would also like to thank, particularly, Mr. C. A. Roberts, engineer of bridges of the Erie Railroad, and officers of the New Haven for furnishing the slides.

This concludes the report of Committee 15. At this time I would like to introduce the vice chairman of Committee 15, Mr. D. V. Messman, engineer of bridges, Southern Railway. [Applause] I might add that Mr. Messman is not only a bridge engineer, but he has a rather long background in school and structural work, and in design, and I am sure he will prove to be a very capable man, eventually, to handle the work of this committee.

This concludes our report, Mr. President.

Erie Bridge 8:45 at Moosic, Pa., showing destruction of pier of this two-span single-track deck plate-girder bridge. Damage was caused by scouring action of Spring Brook which destroyed retaining wall along brook adjacent to pier and undermined the pier. Pier was not supported on piles.

PRESIDENT O'ROURKE: May I add my appreciation—and I'm sure I speak for everyone here—Mr. Wilson, for your lantern slide presentation of bridge structural damage caused by Hurricane Diane on these eastern railroads last fall.

Undoubtedly, much of the damage done by the flood conditions which existed at many points was beyond the realm of prevention by any rational construction or design, but if there were lessons to learn from the disaster, it is well for all of us that we learn them. Thank you again for your presentation, and our thanks also go to those railroads that made the slides available.

Mr. Harris, your committee is excused with the thanks of the Association.

Our first report in the regular order of business this afternoon is that of Committee 29—Waterproofing, the chairman of which is Mr. Henry Seitz, designing engineer of bridges and buildings, Baltimore & Ohio Railroad, Baltimore, Md.

Discussion on Waterproofing

[For report, see pp. 437–439.]

[President G. M. O'Rourke presiding.]

Chairman Henry Seitz (B. & O.): Mr. President, fellow members and guests: The report of Committee 29—Waterproofing, is printed in Bulletin 526, dated December 1955. The committee has three assignments, and we are reporting on Assignments 2 and 3.

No report is being made on Assignment 1—Revision of Manual. However, the committee is reviewing our Manual material, and we realize that revisions are in order for some of the waterproofing materials, procedure for testing materials, and the inclusion of new materials. To develop desirable and practical revisions requires considerable research, and our subcommittees are progressing this work.

The committee has approved the use of carbon tetrachloride in the solubility test for asphalt. This minor revision has not as yet been presented to the Association for approval, since it is expected that other changes will develop from our work, and it is the intent to present these for adoption in the near future.

The report on Assignment No. 2—Waterproofing Materials and Their Application to Railway Structures, will be given by Mr. R. J. Brueske, assistant division engineer of the Chicago, Milwaukee, St. Paul & Pacific Railroad.

Assignment 2—Waterproofing Materials and Their Application to Railway Structures, Collaborating with Committees 6, 8 and 15, was presented by Subcommittee Chairman R. J. Brueske (Milwaukee Road).

Mr. Brueske: Mr. President, fellow members and guests: This report summarizes the results of three separate investigations; one on bitumens, one on coal tar pitch, and one on membranes.

Our bitumen tests were conducted at Purdue University under the direction of J. B. Blackburn. These tests were completed in 1955 and your committee is reviewing the detailed report. This report will be published in an early issue of the AREA Bulletin.

The results of the bitumen tests have confirmed the revisions recently made in the waterproofing specifications. Good basic asphalt materials, that will meet our current specifications, can now be readily obtained from various manufacturers.

An investigation of coal tar pitch is now under way by your committee at Purdue University. We expect the results will enable us to revise this specification in the not too distant future. The testing methods are also being examined to determine the possibility of revision to conform with modern methods.

Membrane waterproofing tests are still in progress at the AAR Research Center in Chicago under the direction of P. D. Miesenhelder of the research staff.

The purpose of this investigation is to determine the behavior of membrane waterproofing under conditions to which it may be subjected in actual use. Such variables as number of plies, type of material, temperature changes, amount of stretch, and reaction to hydraulic head are also being taken into consideration.

We are confident the results of this test will enable us to improve our specification and give us a better understanding of the behavior of membrane waterproofing.

We are still anxious to examine membrane waterproofing that has been in service a number of years. If any of the Association members learn of any membrane waterproofing that is to be uncovered, please notify the committee chairman or Mr. Magee or Mr. Miesenhelder of the AAR research staff.

Mr. President, this report is presented as information.

PRESIDENT O'ROURKE: Thank you; it will be so received.

Is there any discussion on this subject? If not, you may proceed.

CHAIRMAN SEITZ: The report on Assignment 3—Waterproofing Coatings to Prevent Deterioration, will be given by F. S. Schubert, resident engineer of the Chesapeake & Ohio Railway.

Assignment 3—Waterproofing Coatings to Prevent Concrete Deterioration. Collaborating with Committees 6 and 8, was presented by Subcommittee Chairman F. S. Schubert (C. & O.).

MR. SCHUBERT: Mr. President, members and guests of the AREA: In 1951 an investigation of waterproofing bitumens began at the Engineering Experiment Station, Purdue University, under the general direction of Professor H. L. Michael, assistant director, Joint Highway Research Project, with Professors D. W. Lewis and J. B. Blackburn, research engineers, in direct charge. The investigation resulted in the adoption of the Specification for Waterproofing Coatings for Exposed Concrete Surfaces, now appearing in the Manual.

This work completed the previous assignment of Subcommittee 3.

The new work assigned to Subcommittee 3 covers Coatings for Dampproofing of Railway Structures, Collaborating with Committees 6 and 8.

The present specification for dampproofing covers bituminous emulsions only, and the committee recognizes that present-day materials cover a much wider range. Also, the performance of dampproofing materials when applied to walls and abutments is a matter of controversy.

We have been authorized to carry out research concerning these problems at Purdue University and expect the results obtained will permit us to develop a broader and a more desirable specification.

This report is presented as information.

PRESIDENT O'ROURKE: It will be so received.

CHAIRMAN SEITZ: The research work at Purdue University, under the direction of W. H. Goetz, and our committee member Professor K. B. Woods, is being organized, and it is expected that an informative report of progress will be made at this time next year.

The findings on membrane waterproofing at the AAR Research Center will be coordinated with results obtained at Purdue to produce a more modern and extensive specification for waterproofing and dampproofing materials.

If any of those present have any suggestions or questions, we will do our best to answer your questions and profit from your remarks.

PRESIDENT O'ROURKE: Is there any discussion? Are there any questions? Apparently not.

CHAIRMAN SEITZ: Mr. President, this completes the report of Committee 29.

PRESIDENT O'ROURKE: Thank you, Mr. Seitz. The work of your committee, although highly specialized, has important bearing upon the permanence of our masonry structures. We appreciate your keeping us abreast of developments in this field. Your committee is now excused with the thanks of the Association. [Applause]

It will probably be of interest to you all to know that the attendance at the Annual Luncheon today was 1300. Also, the total registration up to noon today was 2,008.

The second report this afternoon will be that of Committee 17—Wood Preservation, of which A. J. Loom, general superintendent timber preservation, Northern Pacific Railway, is chairman. I shall be glad if Mr. Loom and the other members of his committee will come to the platform and make their presentation at this time.

Now that the pressure is off—that we had on this morning—please feel free to get on your feet and discuss these subjects.

[Vice President Hedley assumed the chair.]

Discussion on Wood Preservation

[For report, see pp. 443–471.]

[Vice President Wm. J. Hedley presiding.]

Chairman A. J. Loom (Northern Pacific): Mr. President, gentlemen: The report of Committee 17—Wood Preservation, is on pages 443–471 of Bulletin 526.

Our first assignment was Revision of Manual, and I will ask Mr. C. S. Burt, assistant to vice president, purchases and stores, Illinois Central Railroad, to present the report

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman C. S. Burt (Illinois Central).

Mr. Burt: Mr. President, members: At this time last year this committee brought to your attention a number of Manual material items which were then under study, looking toward revision in each case. We now propose these specific recommendations for your consideration and action:

Page 17–1–3—PRESERVATIVES

Delete the words "Zinc Chloride" from the list of standard preservatives. Zinc Chloride has been replaced as a standard salt preservative by chromated zinc chloride.

Mr. President, I move Manual material covering this subject to reapproved with exceptions as noted in the committee report, Bulletin 526, page 444.

[The motion was regularly seconded, was put to a vote, and carried.]

Page 17–2–1—CREOSOTE

This recommendation has to do only with an editorial change, intended for clarification purposes. It involves restating certain portions of Note 1 under Creosote, and putting some of its content in tabular form.

I move, Mr. President, this material as it now appears in the Manual, page 17–2–1, be reapproved with exceptions as noted in the committee report, Bulletin 526, Page 444.

[The motion was regularly seconded, was put to a vote, and carried.]

Page 17–2–2—CREOSOTE-COAL TAR SOLUTION

This recommendation is quite similar to the one just stated, except that it pertains to Creosote–Coal Tar Solution. It refers to similar explanatory note.

It is recommended the Manual material as it appears on page 17–2–2, Creosote–Coal Tar Solution, should be reapproved with revisions as noted in the committee report as appears on page 445 of Bulletin 526.

Mr. President, I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

Pages 17–4–1 to

17–4–18, incl.—SPECIFICATIONS FOR TREATMENT

This recommendation provides a method of conditioning "ice coated" and "frozen" material prior to treatment with preservatives.

Mr. President, I move reapproval of the Manual material as it now appears on page 17–4–2, Specifications for Treatment, with revisions as noted in the committee report on page 445 of Bulletin 526.

[The motion was regularly seconded, was put to a vote, and carried.]

This recommendation is also intended for clarification in that it provides for showing the net retention of oil-borne and water-borne preservatives in pounds of dry preservative per cubic foot of wood treated.

Mr. President, I move the reapproval of the Manual material in par. 2 and 3, Art. 1, Sec. C, on page 17–4–5, with exceptions as noted in the committee report on page 445 of Bulletin 526.

[The motion was regularly seconded, was put to a vote, and carried.]

To correct an inadvertent transposition of headings, it is recommended that heading of table at the top of page 17–4–10 be changed to read "Lumber, Timbers and Bridge Ties, Con't."—and that the remainder of this material be reapproved without change.

Mr. President, I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

To also correct an inadvertent transportation of headings it is recommended that heading of table at top of page 17–4–15 be changed to read, "Posts"—also that remainder of this material as it now appears in the Manual should be reapproved without change.

Mr. President, I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

You will be interested in knowing of other Manual material items we now have under study looking toward possible revision. They are:

Method of sampling creosote in tank cars.
Flash point of petroleum
Flash point of creosote
Strength requirement of pentachlorophenol solution
Treatment of car materials.

It is our plan to report further on these items.

Mr. President, that completes the report of Subcommittee 1, Revision of Manual.

Chairman Loom: The next is Assignment 2. Mr. R. P. Hughes is the committee chairman. Mr. Hughes is inspector for the manager of treating plants of the Santa Fe.

Assignment 2—Service Test Records of Treated Wood, was presented by Subcommittee Chairman R. P. Hughes (Santa Fe).

Mr. Hughes: Mr. Chairman, gentlemen of the Association: Subcommittee 2 submits the following progress reports on service tests of treated wood:

Chicago, Rock Island and Pacific report on 1955 inspections of cross tie test sections in Iowa, Nebraska, Kansas, Missouri, Texas and Arkansas.

Union Pacific report on 1955 inspections of cross tie test sections at various locations.

Illinois Central report on 1955 inspection of cross tie test section at Canton, Miss.

These reports show the average life to date and the anticipated average life of groups of ties of various kinds of wood and treatments, their dates of insertion and the causes of failure of those which have been removed from track.

We also submit a report by the St. Louis–San Francisco Railway on service records of treated wood in bridges on its Western Division between Tulsa and Enid, Okla.

In conclusion, may I repeat what I said on a former occasion, and ask that any member of this Association who has any records of the service of treated timber should get in touch with this committee, in order that we may have the benefit of such records, to the end that we may be of better service to you.

Mr. President, this report is submitted as information.

CHAIRMAN LOOM: Thank you, Mr. Hughes.

I can only emphasize what Mr. Hughes said about the records. I was on that subcommittee for many years, and it was always a difficult matter to obtain service records that could be printed—as Mr. Hughes has said, for the benefit of our Association.

Assignment 3—Destruction by Marine Organisms, will be presented by A. P. Richards, of the W. F. Clapp Laboratories, Duxbury, Mass.

Assignment 3—Destruction by Marine Organisms: Method of Prevention, was presented by Subcommittee Chairman A. P. Richards (W. F. Clapp Laboratories, Duxbury, Mass.).

MR. RICHARDS: Mr. President, your committee's report this year consists primarily of continuing the progress inspection reports dealing with a number of preservative tests which have been reported on in the Proceedings each year for some time. There is also included a summary giving the relative severity of marine borer activity in a number of harbors, based on long-term studies now being conducted by William F. Clapp Laboratories under the sponsorship of the Navy Department, Bureau of Yards and Docks.

The report is also prefaced by general remarks concerning good preservative practice as applied to marine structural material.

Mr. President, this report is presented as information.

VICE PRESIDENT HEDLEY: It will be so received.

Assignment 4—Petroleum as a Carrier or Extender of Creosote or Pentachlorophenol, was presented by W. C. Reichow, engineer wood preservation, Great Northern Railway.

MR. REICHOW: Gentlemen, this is a comparatively new assignment. All I can say is that there are a number of interesting tests under way upon which we will report some time in the near future.

CHAIRMAN LOOM: Assignment 5 is Destruction by Termites, and will be reported on by Subcommittee Chairman F. J. Fudge, timber engineer of the New York Central.

Assignment 5—Destruction by Termites, Methods of Prevention, Collaborating with Committees 6 and 7, was presented by Subcommittee Chairman F. J. Fudge (New York Central).

[Mr. Fudge read in full the printed report on this assignment, and then continued]:

MR. FUDGE: As information, this appropriation has been approved, and your committee will progress plans for this test. This completes our report at this time.

CHAIRMAN LOOM: Assignment 6—Mr. A. P. Richards of the W. F. Clapp Laboratories, is also the chairman of this assignment, and I will ask him to come up again.

Assignment 6—New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products, was presented by Subcommittee Chairman A. P. Richards (W. F. Clapp Laboratories, Duxbury, Mass.).

Mr. Richards: This year the committee is submitting information and specifications for a new water-borne preservative, and recommends that these specifications be adopted for publication in the Manual. This preservative, chromated zinc arsenate, commercially known as Boliden Salt, has been approved previously by the American Wood Preservers' Association. The U. S. patent on this preservative expired on December 13, 1955, so this material is now eligible for approval by this Association.

Mr. Chairman, I therefore move that at this time the specification for chromated zinc arsenate, printed in Bulletin 526, page 465, be adopted for publication in the Manual.

[The motion was regularly seconded, was put to a vote, and carried.]

Chairman Loom: Assignment 8—W. W. Barger, Santa Fe, subcommittee chairman, is not here. I wonder if I might ask Mr. Hudson to report on this sssignment?

Assignment 8—Effect on AREA Standards and Specifications of Any Changes in Manufacturing Processes and Specifications for Creosote, Petroleum and Other Products, was presented by M. S. Hudson (Consulting Chemist, Spartanburg, S. C.) in the absence of Subcommittee Chairman W. W. Barger (Santa Fe).

Mr. Hudson: Under special assignment, this committee has prepared a table for volume correction factors for preservative salt solutions, and recommends that it be adopted for publication in the Manual. The table of factors is considered necessary because of the fact that new preservative salts have been added to the Manual recently, and you have just added another—Boliden Salt. This table provides factors for changing volumes or correcting volumes to 100 deg F when treating solutions are used at temperatures ranging from 60 to 170 deg.

As a member of the committee, I, therefore, move that the volume correction factors for preservative salt solutions on pages 466 and 467 of Bulletin 526 be adopted and published in the Manual.

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. Hudson: This completes the report on Assignment 8.

Chairman Loom: Next is Assignment 9, to be presented by Mr. W. H. Fulweiler, subcommittee chairman.

Assignment 9—Treatment of Wood to Make It Fire-Resistant, Collaborating with Committees 6 and 7, was presented by Subcommittee Chairman W. H. Fulweiler (Consulting Chemist, Philadelphia, Pa.).

Mr. Fulweiler: Some 20 years ago we started work on this subject under the chairmanship of Dr. von Schrenk. When he retired, I was made chairman, and we have been struggling for a good many years to work this out in a form that would be satisfactory.

You will note the specification is in two parts. One part is a formula for the treating solution, and the second part is the treatment test. You may think it odd that we used the Formulation 2, Formulation 3, and Formulation 4. That was necessary because these formulas are registered trade-marks, and the Association doesn't permit the use of such names in their specifications.

I would, therefore, like to move that the Association accept the report and adopt the specifications and appended comment contained in it, which appear on pages 468, 469 and 470 of Bulletin 526, for inclusion in the Manual.

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. Fulweiler: This concludes the report on Assignment 9.

Chairman Loom: Our last assignment is No. 12, to be reported on by Mr. L. C. Collister, manager, tie and timber treating department, Santa Fe Railway.

Assignment 12—Treatment of Laminated Timbers, Collaborating with Committee 7, was presented by Subcommittee Chairman L. C. Collister (Santa Fe).

[Mr. Collister read in full the published report on this assignment, and then continued]:

MR. COLLISTER: Your attention has been called to the treated and untreated laminated samples in the foyer, just outside the Grand Ballroom. For those of you who are interested, I would again like to call your attention to the treatment of those laminated pieces. The treatment is and can be as good or better than the treatment of solid sections of the material.

This is for information, and is so reported.

VICE PRESIDENT HEDLEY: Thank you, Mr. Collister.

CHAIRMAN LOOM: Mr. Chairman, that completes the report of Committee 17.

VICE PRESIDENT HEDLEY: Thank you, Mr. Loom. You have made a number of very interesting reports. The Association greatly appreciates this work, appreciates the enthusiasm with which it has been undertaken, and the evident interest in keeping up the Manual material for which your committee is responsible.

Your committee is now excused with the thanks of the Association.

The next committee to report is Committee 6—Buildings.

We begin this presentation on a note of sadness because, as President O'Rourke mentioned at the luncheon, the chairman of this committee, Mr. O. W. Stephens, engineer maintenance of way of the Delaware & Hudson Railroad, passed away last Saturday. Under the circumstances, I shall call upon the vice chairman of the committee, Mr. D. E. Perrine, assistant chief engineer, Chicago & Western Indiana Railroad, to conduct the committee's presentation.

Mr. Perrine, will you and the other members of your committee please come to the platform?

Discussion on Buildings

[For report, see pp. 381-396.]

[Vice President Wm. J. Hedley presiding.]

CHAIRMAN D. E. PERRINE (Chicago & Western Indiana): Mr. President, members of the Association and guests: Before proceeding with the presentation of our report, Committee 6 wishes to express its deep sorrow at the passing on March 10, last Saturday, of our esteemed chairman, Mr. Orville W. Stephens, engineer maintenance of way of the Delaware & Hudson Railroad. We of Committee 6 have been saddened by this news, received just before the opening of the convention. A suitable memoir in his honor will be prepared and included in the presentation of our committee in the Proceedings.

MEMOIR

Orville William Stephens

Orville William Stephens, engineer maintenance of way, Delaware and Hudson Railroad, at Albany, N. Y., passed away at his home in Albany, March 10, 1956. He was born at Carbondale, Pa., May 29, 1900, the son of Mrs. Carrie Jeffrey Stephens and the late Charles E. Stephens. He is survived by his wife, Betty Martin Stephens, his mother, and a sister, Mrs. Ellen Stahl.

Mr. Stephens attended the University of Michigan from which he received a B. S. degree in civil engineering in 1925. He entered the service of the Delaware and Hudson

as a draftsman at Plattsburg, N. Y., in 1925, subsequently serving as transitman, bridge and building supervisor, and track supervisor. He was advanced to assistant to chief engineer—maintenance, at Albany in 1949, and became engineer maintenance of way there on January 1, 1956.

Mr. Stephens joined the AREA in 1942 and was appointed a member of Committee 6 in that year. He served as vice chairman, 1951 to 1954, and was chairman from 1954 until his death. He had also served on Committee 28—Clearances since 1950.

He was a member of a Masonic Lodge in Albany, a registered professional engineer and land surveyor in New York State, and a member of the Albany Chapter of New York State Society of Professional Engineers and of the National Society of Professional Engineers. Mr. Stephens was interested in the civic affairs of his city, being a director of the Railroad Y. M. C. A. of Albany and a member of the Albany Railroad Community Committee. He was also a member of the Albany Country Club.

The Building committee, valuing Mr. Stephens leadership, ability, energy and friendship, feels keenly its loss in his passing and will miss him as a friend and fellow worker.

Mr. Perrine: The report of Committee 6 is found in Bulletin 525, November 1955, beginning on page 381. While progress has been made on eight assignments during the year, the committee will report on only one assignment, and will present a special talk on the painting of frame buildings.

The report to be submitted is on Assignment 3—Shop Facilities for Diesel Locomotives. Mr. W. F. Armstrong, architectural engineer, Chicago & North Western Railway, is chairman of the subcommittee, and will present the report.

Assignment 3—Shop Facilities for Diesel Locomotives, Collaborating with Electrical Section, AAR, Committee 12, Fire Protection and Insurance Section, AAR, Committee 2, and AREA Committee 14, was presented by Subcommittee Chairman W. F. Armstrong (C&NW).

Mr. Armstrong: Mr. President, members of the Association and guests: Last year your committee presented as information a report on Shop Facilities for Diesel Locomotives (Proceednigs, Vol. 56, 1955, pages 429 to 444, incl.), and requested comments and criticisms thereon. This report has been revised, and is now submitted with the recommendation that it be adopted and published in the Manual.

Mr. President, I move that the report on Assignment 3—Shop Facilities for Diesel Locomotives, appearing in Bulletin 525, pages 382–396, be approved for inclusion in the Manual.

Vice President Hedley: You have heard the motion on the approval of this rather extensive material on shop facilities for diesel locomotives. Is there a second?

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. Armstrong: Mr. President, that concludes the report on Assignment 3.

Vice President Hedley: Thank you.

Chairman Perrine: This completes the report on our regular assignments. As a special feature, we have arranged for an address on the painting of frame buildings, a subject of vital importance in the construction and maintenance of railroad structures.

The Forest Service of the United States Department of Agriculture maintains the Forest Products Laboratory at Madison, Wis. The laboratory investigates all phases of wood, wood products, their uses and preservation. For the past 34 years the laboratory has been engaged in paint research. For 20 years, Mr. Don F. Laughnan, a graduate of

the University of Wisconsin, has been in the painting and finishing research section, and is now head of that section. He is well qualified on the painting of wood surfaces. It gives me great pleasure to introduce Mr. Don F. Laughnan, of the Forest Products Laboratory.

Painting Frame Buildings

By Don F. Laughnan

Technologist, Forest Products Laboratory, United States Department of Agriculture

We might get this discussion underway with the question "Why do we paint the exterior of wood buildings?" The answer is "We paint primarily for the purpose of decoration—to change, enhance or improve the natural appearance of wood."

Of course, paint also provides some protection for the wood. To understand the nature and the extent of this protection, we must know something of what happens to wood that is exposed out of doors. Wood exposed to the elements may be subject to one of two deteriorating influences—weathering or decay. Either of these actions, if permitted, will finally cause complete disintegration of wood.

Weathering of wood is due partly to physical and partly to chemical changes in the wood. The physical changes are the result of the repeated unequal swelling and shrinking that accompany wetting and drying of the exposed wood surface. These changes occur with the ever-changing humidity of the atmosphere and, of course, with rain and sunshine. The surface layers of wood respond very quickly to these changes, but the inner portion of the wood lags behind because of the relatively slow rate of transfusion of moisture in wood. This lag tends to keep the interior at a relatively uniform moisture content and a constant volume, so that when the outside wood fibers swell and shrink they are alternately squeezed together and pulled apart.

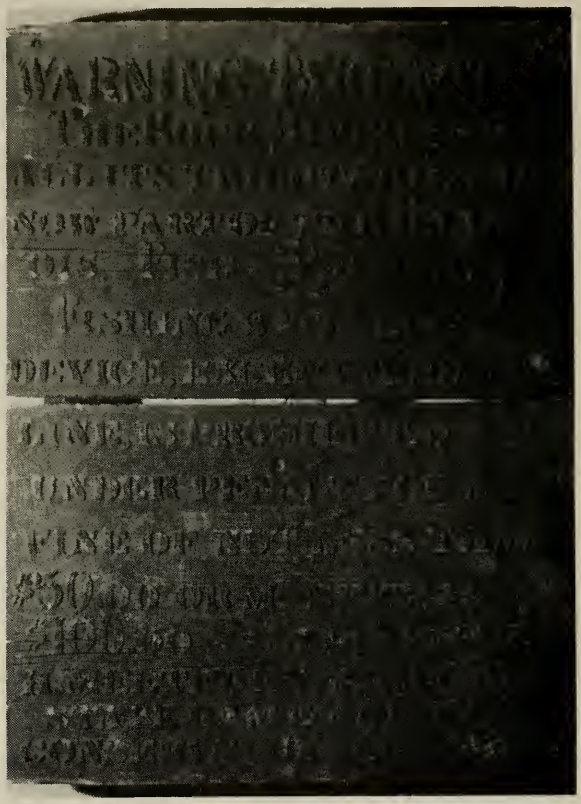
The chemical changes result from the action of sunlight, air and water on the surface layers of the wood. A gray layer develops on the exposed surface. Both cellulose and lignin become partly solubilized and leached from this layer and the brown layer immediately underlying the gray layer.

The combination of physical and chemical changes results in a very slow breaking down and wearing away of the surface fibers and more noticeably in grain raising, checking, cracking, splitting, cupping, warping and pulling at fastenings. In addition, it results in the wearing away of wood from the surface at the rate of about ¼ in in a century.

Decay, on the other hand, is caused by the action of wood-destroying fungi—small living organisms that actually feed on the wood substance. The visible effect is familiar to everyone as "rotten" wood. Wood that is rotten or decayed has not been simply disintegrated as is the case in weathering; it has been actually decomposed.

Weathering and decay are not usually found in the same place. Wood that is dry will not rot, because the fungi must have water to live. On the other hand, weathering is usually found where the wood as a whole remains fairly dry. The surface layers of the wood periodically take up moisture, but drying occurs before the water can penetrate to the interior of the wood and thus support decay.

Protection against weathering can be provided by coatings of paint or varnish. Such coatings, though they are not impermeable to moisture, protect the wood enough to prevent rapid changes of moisture content in the surface layers and thereby prevent the wood from weathering. Coatings do not preserve wood against decay. Where decay is likely to occur, a naturally durable wood should be selected or, better yet, the wood



Paint protects wood against weathering. The lettering but not the background of this wood sign was painted in 1913. When sign was removed in 1938, the background had weathered away, leaving the painted letters about 1/16 in. in relief.

should be impregnated with a preservative chemical that is toxic to decay organisms. Some well known chemicals of this kind are creosote, pentachlorophenol, and copper naphthenate.

In the New England area and in other areas of the country, there are houses more than 250 years old that were never painted. It is apparent from this and other evidence that wood is a durable building material and, in fact, is commonly referred to as a permanent building material. Wood siding will, on its own, outlast many, many times the most durable paint. It should be obvious then that we could not economically paint wood for the sole purpose of protecting it. On a dollar-and-cents basis we would be far ahead to give wood siding, for example, no protection and simply replace it when it wore out.

Among the various ways of dealing with the exterior of a house or other structure, the least expensive procedure is to leave the exterior completely untreated or unprotected. If this plan is to be followed, the building should be sided with one of the woods that weather well, such as western red cedar, redwood or cypress, and exterior lumber of

These pieces of wood were painted on all surfaces with aluminum paint for wood, a paint of high protective power. They decayed nevertheless.

substantial thickness should be used in the structure. It is well also to nail with a little more care than is generally given where the exterior is to be protected. Actually, weather-beaten wood is well adapted to only a limited number of architectural designs and to spacious rustic settings. This explains why there are so few buildings treated in this manner.

The exteriors of most houses are finished with one or more of three broad classes of finishes: (1) stains, 2) natural finishes, and (3) paints. Good shingle stains are inexpensive and durable. They come mostly in dark browns, greens, reds, and yellows. They penetrate into and color the wood, obscuring its grain but leaving little or no film on its surface. Rough-sawn or weathered wood surfaces are especially suitable for shingle stain. A good shingle stain should last at least 5 years and may last as long as 9 or 10. Since stain does not form a continuous film on the surface of the wood, it does not protect the wood against weathering. Therefore, if a wood is to be stained it is desirable to select a wood that weathers well and gives long service without any protection whatsoever. Best of our native species of wood on this score are the cedars, redwood, and cypress.

Natural Finishes

Natural finishes have become popular in the last 10 years. They are used in an effort to retain the natural appearance (color and grain) of wood. These finishes may be classified into two types: the penetrating finishes which may be clear or pigmented and the surface coating or film-forming finishes which are usually clear.

Natural finishes of the surface-coating type are chiefly spar varnishes. They may give a lustrous or glossy finish, or a dull or matte finish. No really durable natural finish of this type has been developed.

The penetrating natural finishes leave little or no continuous coating on the surface. They include the oil finish, the wood-sealer finish, and the water-repellent finish. All three types look somewhat better and last longer if they contain some durable pigments. Usually, the reddish-brown iron-oxide pigments are used for this purpose.

Neither the penetrating nor surface-coating types of natural finishes are nearly so durable as paint and therefore need to be renewed much more frequently than paint, usually every year, or at the most, every two years. Even with such attention and care, the surface-coating types of natural finish may ultimately need to be removed completely to restore a satisfactory finishing surface. The penetrating finishes are less exacting in their maintenance requirements and do not fail as conspicuously as the surface-coating finishes, so they are to be preferred.

House Paints

House paint is by far the most widely used finish for wood siding. White house paint is still the most popular. A good white house paint should last at least 4 to 5 years before it must be renewed, tinted paints a year or two longer, and dark-color paints 6 to 8 years, occasionally longer than that.

To give you some understanding of the situation that prevails in the paint industry, there are approximately 1500 paint manufacturers in this country. There is no general agreement between them concerning the best type or types of paint. There are no standards of quality in the paint industry. So, the buyer of paint has exceedingly little to go on. He cannot purchase a grade of paint as he can wood siding and many other things. In fact, it is the rare house owner who can differentiate between good and poor quality paint even if the composition of the paint is printed on the label, and in some instances it is not. He is therefore left to his own resources, which are discouragingly meager—he must rely on his own past experience with a given manufacturer's paints (and the composition of paints is constantly subject to change) and perhaps on his own and his neighbors' experience with different types of paints. At the very least, then, he should have a statement of composition of the paints he is considering. With this information, we at least can help him by classifying the paints and apprising him of the strong and the weak features of the different types.

House paints may be classified simply, according to the pigments used in them, into six basic kinds or types: (1) titanium-lead-zinc paints, (2) titanium-zinc paints, (3) titanium-lead paints, (4) titanium paints, (5) white lead paint, and (6) dark-color paints.

Each of these types of paint has some of the characteristics generally considered essential in good house paint. These include durability sufficient to last 4 to 6 years before needing to be renewed, a normal form of wearing away that assures a good repaint surface with a minimum of preparatory work, and a sufficiently fast rate of wear to prevent the accumulation of an excessively thick film of paint when a reasonable maintenance schedule is used (1 coat every 4 or 5 years, or 2 coats every 6 years). Included,

as well, are a clean, highly reflective color and the ability to remain free from excessive dirt collection in service. Paint should also be nonsensitive to moisture, and should not be stained by products of metal corrosion. Neither should it be discolored by hydrogen sulfide or organic sulfide.

No one type of house paint on the market has all of these characteristics. All have some desirable features and some that are not so desirable. In order to select the type of paint that is likely to give the most satisfactory service on his house, the home owner should be familiar with the conditions to which house paints are subjected in his area. He must also know which types of paint will stand up best under these conditions—which of the various properties of paint are important to him under the circumstances and which are relatively unimportant.

The type of paint now made in greatest volume is the titanium-lead-zinc paint. The content of lead and zinc in this type of paint varies over a wide range. In general, though, the lead content is steadily declining—some of the larger paint manufacturers have eliminated it altogether, with the result that the titanium-zinc type of paint is now made in a volume approaching that of the titanium-lead-zinc type. Together, these two types of paints probably constitute as much as 75 percent of all of the house paint made in the country.

The titanium-lead-zinc and titanium-zinc types of paints are very much alike in their properties. The chief difference is that the titanium-zinc paints contain no lead or other pigments that react with hydrogen sulfide to form metallic sulfides of dark color. It is for this reason that they are often called "fume-proof" paints and recommended for use where sulfide discoloration is a problem. Desirable properties which these two types of paint have in common include a brilliant, highly reflective color, good drying properties, mildew resistance, the ability to remain clean in service, and good durability. However, they are generally hard, so they wear away comparatively slowly. They normally fail by cracking, curling, and flaking which necessitates precautions—the film of paint must not be permitted to become too thick and, on the other hand, the failure must not be permitted to advance too far before repainting is done.

We, at the Forest Products Laboratory, have found that zinc-containing paints swell much more than wood when wet and, of course, much more than paints without zinc oxide. Such paints blister more readily on contact with water than those paints containing no zinc oxide. Under some conditions, contact with water may not result in blistering but may simply bring about premature cracking, curling, or flaking. We believe that sensitiveness to water is the most serious shortcoming of the zinc-containing paints.

Paints of the titanium-lead, straight white lead, and titanium types, as well as those dark color paints made without zinc oxide, swell more on the order of wood when wet by water. The extent of swelling is much less than is the case with the zinc-containing paints. Therefore, such paints have much less tendency to blister than do the zinc-containing paints. Hence, we refer to them as "blister-resistant" paints. The type of "blister-resistant" paint with which there has been most experience is, of course, white lead paint, which prior to about 75 years ago was the only white paint used on houses. We might dwell for a moment on the properties of white lead paint. It is a durable paint that fails normally by checking and crumbling, a pattern of failure that leaves a good repainting surface requiring little preparatory work. It is a comparatively soft paint that wears away at a faster rate than most other paints. This is desirable because it means that there is less risk of building the paint film up to excessive thickness. It is resistant to staining by rusting metal. Probably the most important of its properties is its nonsensitiveness to water. Even when exposed to water for a long time, it swells only

about as much as wood does when wet. As a consequence, it has little tendency to blister.

White lead paint also has some disadvantages, some of which have led many house owners to prefer other types of house paint. For one, it has an off-white color that does not compare favorably with the intense, brilliant white of most other paints. For another, it is given to serious dirt retention. Despite the fact that it wears away faster than other paints, it collects more dirt and retains it longer than most other types of paints. Another serious objection is its property of discoloring on contact with hydrogen sulfide and some organic sulfides that cause the formation of black lead sulfide. Finally, white lead paint is somewhat more expensive than the other types of house paints.

In recent years, paints made with titanium and lead pigments, but with no zinc oxide, have appeared on the market. Some paints of this kind are sold as "breather-type" paints. In addition to titanium and lead, such paints contain a considerable quantity of transparent or extending pigment, and are made with a high proportion of pigment to binder so they are characterized by a lack of gloss.

A few paints pigmented with titanium and lead are sold as "titanized white lead." Some paints of this kind contain no extending pigments. They are made with the convential ratio of pigment to binder and therefore have as much gloss as the zinc-containing paint.

Paints of the titanium-lead type are nonsensitive to moisture and therefore blister resistant. They have high opacity and generally stand between white lead paint and the zinc-containing paints in color, in resistance to soiling by dirt and staining by rusting metal, and in the rate at which they wear away. They do, however, fail by checking and crumbling, which is desirable because it provides a surface that is easy to repaint. On the other hand, they, like pure white lead paint, are discolored by hydrogen sulfide.

Paints made with titanium pigment (but no lead or zinc) and one of several special vehicles are now available. One of the vehicles used is a long-oil alkyd resin; another is referred to as a copolymer solution. This type of paint is sold as "blister- and stain-resistant" paint. Like the breather type of paint, it has little or no gloss. In opacity, color, and resistance to soiling by dirt and staining by rusting metal, it is like the titanium-lead paints. It differs from such paints in that it is enamel-like in its characteristics and resists sulfide discoloration. Such paint normally fails by cracking, curling, and flaking, and indications are that it wears away at a rate similar to that of the titanium-lead paints.

Dark-color paints, sometimes called trim paints or trim-and-trellis paints consist chiefly of dark-color pigments and little, if any, titanium dioxide, white lead, or zinc oxide. In most trim paints the major portion of the vehicle is varnish, usually an alkyd-resin varnish. Iron-oxide paints—the familiar red barn paints—may also be classified as dark-color paints. They are sometimes used on houses, and, if properly made, are very durable. In general, good paints of dark colors are more durable than any white or light-colored paint and less sensitive to water than are white or light-colored paints made with zinc oxide.

Now a word about paint primers, since the choice of a primer can do much to insure a long-lasting, trouble-free paint job. In particular, a primer should be free of zinc pigments, even if a zinc-containing paint is used for the finish coat. Most paint makers provide special, zinc-free house-paint primers or undercoaters for use with their mixed-pigment paints containing zinc. Some paints made without zinc oxide may be used as self-primers. In any case, it is wise to use primer and finish paint of the same brand.

Paint blistering caused by cold-weather condensation. The brown discoloration on the paint film is caused by the water-soluble color extractives that occur in some woods.

Flat-grained woods with wide summerwood bands such as Douglas-fir and southern yellow pine, or wood with knots, should be primed with a special primer. We have found that aluminum house paint, sometimes called "aluminum paint for wood", is best for this purpose.

Selection of a particular type of house paint requires careful thought. The experience of others in the neighborhood and city may be helpful in finding out what types of difficulties with paints are common and which paints serve best. The construction of the house should also be considered. Does it have a wide roof overhang to shield the walls? Has it adequate gutters and down-spouts, and are they properly installed? Is there a good vapor barrier along with the insulation? If the answers are "yes" to all of these, a zinc-containing paint stands a fair chance of success (but only over a zinc-free primer) and only if a sensible maintenance program is adopted. If there is doubt or if one or more of these conditions cannot be met, one of the zinc-free paints is the wiser choice.

We often hear the claim that the quality of house paint is better now than it has ever been—that the widespread difficulties being experienced with paint on wood houses is due to the fact that our wood siding is of lower quality than it used to be. This is not a true picture of the situation.

Let us look at wood for a moment. The Forest Products Laboratory more than 20 years ago classified the commercially important species of this country into five groups on the basis of their paintability: Group 1, the cedars, redwood, and bald cypress; Group 2, eastern white pine, sugar pine, and western white pine; Group 3, white fir,

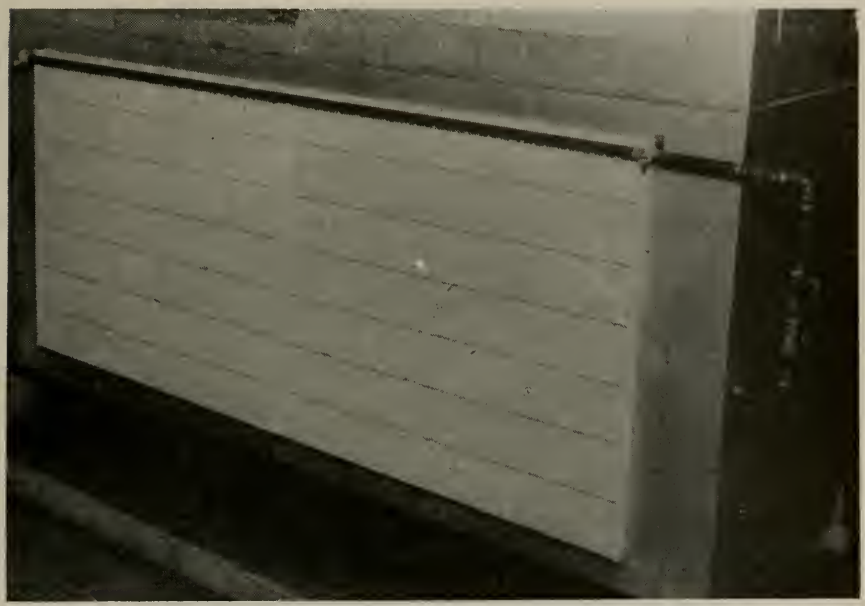
When paint films build up to excessive thickness, the films will crack at right angles to the grain of the paint, the grain being determined by the last strokes of the brush at the time the paint was applied.

the hemlocks, ponderosa pine, and the spruces; also such hardwoods as aspen, basswood, cottonwood, magnolia, and yellow poplar; Group 4, Douglas fir, southern yellow pine, and western larch of the softwoods; of the hardwoods, beech, birch, the gums, and maple; and Group 5, ash, chestnut, elm, hickory, oak, and walnut, all of which are hardwoods with large pores.

Among the softwoods, the painting characteristics of a board depend primarily upon the amount and distribution of summerwood. The width of the summerwood bands in softwoods usually varies with the density of the wood and the rate of tree growth, being narrower when the density is low or the tree growth is slow. Edge-grained boards have narrower bands of exposed summerwood than flat-grained boards and, therefore, hold paint better and longer.

It is true that less than 10 percent of the wood available to us for exterior building use is of the more desirable species with respect to paint-holding ability. But this situation has not altered greatly in the last 25 years, at least not enough to account for the increasing incidence of house paint failures. Edge-grained western red cedar holds paints as well and as long today as it did 25 years ago. Conversely, it is about as difficult to maintain coatings of paint on the softwoods that have wide summerwood bands today as it was 25 years ago.

We have been making mistakes with our house paints: first of all, we have gone heavily to water-sensitive types of house paints, paints that blister with less provocation than the house paints of old; our paints now are made with less nonvolatile per gallon—less film-forming material per gallon, than used to be the case and yet we try to get by



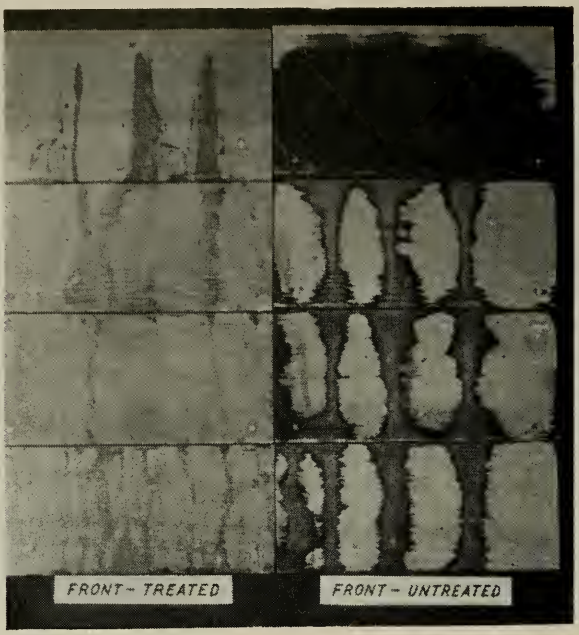
Blistering box developed by the Forest Products Laboratory. The box has been used to blister paints by cold-weather condensation as well as by water flowed over the painted face of siding to simulate rain.

with two coats for the original paint job on new houses. The Forest Products Laboratory did a great deal to establish two-coat painting as a sound practice, but the paints for this purpose have to be made specially. Today's paints will not meet the requirements—three coats are required for the original paint job.

We now think of house construction as a year-round occupation. Houses completed in the winter months are usually primed, but an interval of 4 to 8 months may elapse before the top coat is applied. Too often the top coat fails to bond properly to the prime coat—it separates from the prime coat in what we refer to as "intercoat peeling." It is better to delay all the painting of the exterior of such houses until warmer weather arrives because the individual coats of a given paint job should be applied within weeks of each other.

The same thing is likely to happen when the paint on a new house, that received a scanty coating of paint to begin with, fails after a year or two and the owner feels prompted to apply just one more coat of paint at that time. To be on the safe side, a house paint film should be permitted to weather a minimum of 3 years, and preferably 4, before new paint is applied over it.

Possibly the most serious form of paint failure is blistering and peeling. Most, but not all, blistering and peeling is caused by water that gets into the side walls back of the paint coating. Such water may come from several sources, but the two most important are: (1) cold-weather condensation—water vapor within the house passes into the side walls where, during cold weather, it condenses out as liquid water and may later diffuse through the sheathing and siding and cause the exterior paint to blister; (2) rainwater that penetrates into the lap and butt joints to the back of the siding.

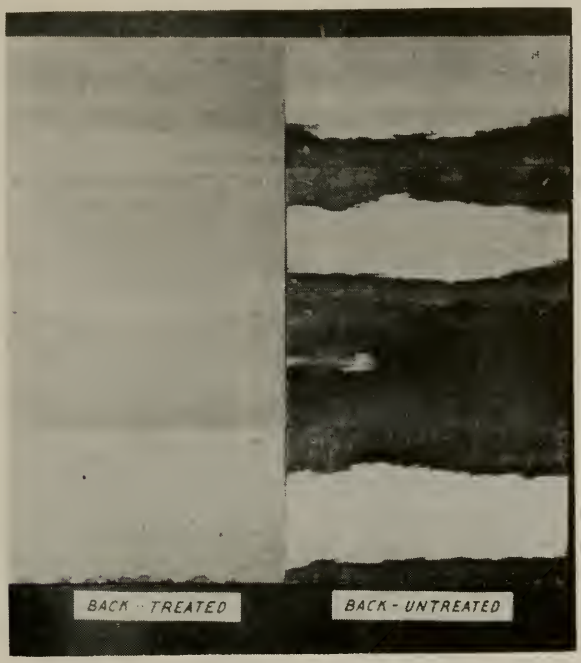


Two matched panels of western red cedar siding. The panel on the left was dipped for 10 sec in a water-repellant preservative: that on the right received no treatment. Water containing a green dye was flowed over the face of both panels.

Much has been said and written about cold-weather condensation as the cause of paint blistering, but it is not generally known that rainwater is an equally serious cause of paint blistering. We, at the Forest Products Laboratory, have reason to believe that rainwater that works through the joints to the back of the siding is the cause of as much, if not more, paint blistering than cold-weather condensation.

Fortunately, there are symptoms that enable one to determine the source of water that is causing paint failure. When blistering results from cold-weather condensation the blisters appear in the very early spring; blisters are usually more extensive on the north side of the house because that is the coldest side, and they may be concentrated outside the kitchen and bathroom, rooms in which the relative humidity is usually higher than in the balance of the house. Blisters from this source occur on siding that is protected by roof overhang as well as on unprotected siding, but they occur only on heated buildings.

In contrast, blisters brought about by the penetration of rainwater through the joints in the siding occur later in the spring and through the summer (during the rainy season). The blistering is usually most severe on the south and west sides of the house because the prevailing winds are from those directions, and it occurs only on siding that is unprotected—the paint on the siding immediately under roof overhang is not ordinarily wet by rain and therefore does not blister under these circumstances. Paint blistering caused by rainwater may occur on unheated as well as on heated buildings.



The extent to which water penetrated the joints in the untreated panel is evident from the extent of staining in the back of the right hand panel. The treatment prevented the penetration of water through the joints in the left hand panel.

Cold-weather condensation is best eliminated by providing a vapor barrier on the warm side of the exterior walls and on the ceiling. In the colder areas of the country, a vapor barrier should be installed at the time of construction. Aluminum foil, polyethylene film, and some asphalt-coated papers serve as good vapor barriers. In existing houses built without a vapor barrier, the practicable means of providing one is by painting the interior surface of the exterior walls with a paint of higher moisture-excluding effectiveness. Aluminum paint serves this purpose well and some of the oil-base and latex paints are nearly as effective.

Penetration of rainwater through the joints in siding can be eliminated by treating the siding with a water-repellent preservative before it is painted. This is a solution of a small amount of wax, some resin and drying oil, together with a fungicide in a paint thinner, such as mineral spirits. Such solutions have been used in the millwork industry for nearly 20 years, and today most millwork is treated with a water-repellent preservative.

Wood siding is best treated by dipping in a water-repellent preservative before the siding is nailed in place, but brushing the solution on after the siding is in place is satisfactorily effective. In fact, treatment with such a solution is effective even on painted siding. If it is to be used on a house on which the paint is blistering as the result of rainwater penetrating through the joints, all loose and curled paint should be removed. Then the solution should be brushed on at the lap and butt joints. The solution that is

deposited on the paint film itself should be removed by wiping with a cloth wet with paint thinner.

The house owner brings other troubles upon himself, troubles that he might avoid if he were educated in the use of house paint. For one thing, it is the rare house owner who remembers, from one repaint job to the next, what type of paint he last applied on his house. When it comes time to repaint, he selects a paint without regard for the paint previously applied on his house, and runs the risk of building up a paint film of widely dissimilar paints, which may fail as the result of incompatibility. He should properly select a good-quality paint at the time of the construction of the house and continue to repaint with that same type of paint throughout the useful life of the house.

Too many house owners overpaint, either to restore a clean, fresh appearance to the house or to change colors in keeping with the type. A safe paint-maintenance schedule consists of 2 coats at 6-year intervals or, at the most, 1 coat at 4- or 5-year intervals. Painting more frequently may ultimately lead to excessive film thickness at which point cross-grain cracking may occur. Once this type of failure occurs, the only truly satisfactory means of restoring a good painting surface is to remove the old paint completely down to the bare wood and start over. This is a time-consuming and expensive chore, and the houseowner faced with this task cannot be blamed for looking around for substitute covering materials to cover over his mistakes. Many house owners resort to the use of such materials, and the end result is that wood siding and house paint designed for use on it have lost a friend. Too often the loss is a needless one—one that could have been avoided had the house owner been properly educated in the use of paint and wood.

Vice President Hedley: Thank you, Mr. Laughnan.

Chairman Perrine: Thank you, Mr. Laughnan, for your interesting and informative talk on a subject that is of great importance to each one of us. I am sure that Mr. Laughnan and his associates will welcome any visitors to the Forest Products Laboratory at Madison. In fact, he told me they definitely will welcome anyone who comes up there to look at their testing, and the other things they are doing.

The Laboratory publishes a number of manuals and bulletins on the various phases of paints and painting practices. These are available on request.

Mr. President, this concludes the report of Committee 6.

Vice President Hedley: Thank you, Mr. Perrine, and Mr. Armstrong, for the very comprehensive material with respect to shop facilities for diesel locomotives, prepared under your direction for inclusion in our Manual. This material is a most welcome addition to the Manual, and I am sure will prove a helpful guide to many with respect to diesel shop design and layout in the future.

I know your committee has made substantial progress on a number of other assignments, and we are in hopes you will be in position to report on them next year.

We greatly appreciate the interesting presentation on painting by Mr. Laughnan, as representing a subject which is of major importance and concern to the railroads.

Thank you again, Mr. Perrine. We know it has been with a heavy heart that you have performed your task this afternoon, but we are glad that you will carry on, as we know Mr. Stephens would want you to do.

Your committee is now excused, with the thanks of the Association.

[President O'Rourke resumed the chair.]

PRESIDENT O'ROURKE: Turning to the important subject of work equipment, our next report will be that of our Committee 27—Maintenance of Way Work Equipment, the chairman of which committee is Mr. N. W. Hutchison, engineer of work equipment, Chesapeake & Ohio Railway, Barboursville, W. Va.

I shall be glad if Mr. Hutchison and members of his committee will please come to the platform and present their report, and may I ask especially that all reporting subcommittee chairmen take places near the podium to avoid lost time in coming to the podium to make their presentations.

Discussion on Maintenance of Way Work Equipment

[For report, see pp. 473–528.]

[President G. M. O'Rourke presiding.]

CHAIRMAN N. W. HUTCHISON (C&O): Mr. President, members and guests: Those of you who have with you Bulletin 526 will find the report of Committee 27 on pages 473–528, incl. We are reporting on nine assignments, two of which are progress reports, and seven of which are final reports. All of the reports are submitted as information only.

Our presentation of these reports will be confined to brief summaries, but this committee feels that those who are interested in work equipment will find much of value in the reports, and suggests that they be read in their entirety.

We should like to emphasize the fact that our first report, Assignment 3—New Developments in Work Equipment, is a continuous one, and each year an effort is made to include a brief description of all of the new and important developments in the work equipment field. A summary of this report will be presented by the subcommittee chairman, Mr. H. H. Hall, associate editor, Railway Track and Structures.

Assignment 3—New Developments in Work Equipment, was presented by Subcommittee Chairman H. H. Hall (Railway Track and Structures).

MR. HALL: Mr. O'Rourke, and gentlemen: This assignment, New Developments in Work Equipment, is, as Mr. Hutchison has told you, a continuing one. It represents an effort on the part of Committee 27 in general, and Subcommittee 3 in particular, to present to you, in capsule form, the latest developments in new machines and important improvements in or attachments applicable to existing machines. This year, your subcommittee is reporting 21 new machines and improvements to 4 machines, which have been brought to its attention since the report of last year.

Six of these machines are directly applicable to track maintenance. These include an automatic gang tamper of the production type, which makes use of a new principle of vibration and has a completely automatic tamping cycle; and a one-man operated, completely hydraulic, self-propelled, 4-unit tie tamper, which tamps the tie under one rail. Both of these machines are designed for track surfacing operations. In this group are two machines applicable to tie renewal work with tie gangs; a tie-bed cleaner, which is designed to scarify, loosen and clean the tie bed without raising the track; and a tie handler designed to serve the dual purpose of a tie remover, with the addition of a boom, and a tie inserter, with the boom removed. The last two machines, for use in rail renewal operations, are a ballast router, which removes and conveys high ballast from the cribs to the side of the track and sweeps the ties in advance of the adzers; and a dual-spike driver, which drives two track spikes simultaneously.

An airless spray painting system has been described; as has a portable spray gun outfit applicable to the spraying of paint and other materials; and a rotary paint scraper

for the removal of paint. A diaphragm pump for the handling of sludge or use in dewatering operations, and a positive-displacement pressure pump for fire protection service have been included.

Among the larger pieces of equipment are a diesel-electric pile driver for heavy-duty on-track service, and a transit crane which is rubber mounted for over-the-road service. The report includes a mobile, hydraulically-operated personnel lift adaptable for use in painting, inspecting and the maintenance of overhead facilities; a tractor-mounted, air drill rig; a truck-mounted generator, which secures its power from the truck motor; an air-powered saw, usable underwater as well as in regular service; and a small ditching machine which will dig up to foundations and under sidewalks.

Items for the transportation of machinery and equipment include an electrically-driven under carriage for welding generators; a lightweight push car, which can be separated into two sections to facilitate loading for over-the-road transportation; and a motor car carrier, which is a trailer, designed for over-the-road transportation of track motor cars.

Appliances and modifications designed as improvements to existing machines include a crossing scarifier used as a front-end attachment for a ballast regulator; a double-barreled stud driver, which has two interchangeable barrels for driving studs into steel or concrete; an hydraulic sickle-drive modification of an on-track weed mower; and a power lift for application to derrick cars.

CHAIRMAN HUTCHISON: Thank you, Mr. Hall.

The next report is No. 4—Improvements To Be Made to Existing Work Equipment. The report under this subject will be summarized by R. E. Berggren, supervisor maintenance of way equipment of the Illinois Central Railroad.

Assignment 4—Improvements To Be Made To Existing Work Equipment, was presented by Subcommittee Chairman R. E. Berggren (Illinois Central).

MR. BERGGREN: This is a progress report, submitted as information, being a continuation of reports submitted by this committee in previous years. It covers changes in existing work equipment that the committee has found to be both desirable and practical.

The current report is confined to several improvements which we suggest be made to five machines to improve their operation, extend their life or to facilitate their maintenance.

These machines are: Track liner; track gager; track jack and tamper; power ballast regulator; and spike puller.

All of the recommended improvements listed were submitted to the manufacturers of the equipment for their consideration. They expressed their gratitude for these suggestions and advised that they would cooperate as far as possible in effecting the desired changes.

CHAIRMAN HUTCHISON: The next assignment is that on Pneumatic Tires and Tubes. This report will be presented by F. L. Horn, engineer of track, Terminal Railroad Association of St. Louis.

Assignment 5—Pneumatic Tires and Tubes, was presented by Subcommittee Chairman F. L. Horn (Terminal Railroad Association of St. Louis).

MR. HORN: Mr. O'Rourke, members: The last decade has witnessed the rapidly increasing use of automotive highway vehicles for transporting the men and materials necessary to the construction and maintenance of the physical plants of the railroads,

and the use of many heavy off-track machines to perform work formerly done by on-track machines. All of the automotive vehicles and an increasing percentage of the off-track machines are mounted on pneumatic tires. As a result, tens of thousands of pneumatic tires and tubes, ranging in size from 4:00–8:00 wheelbarrow and set-off wheel tires to 30.00–33 earthmover tires, are in service on the railroads. This report presents information which can assist railroads in proper tire, tube, and rim selection and the establishing of proper tire maintenance and repair procedures.

The correct combination of tire, tube, and rim must be selected for the load and type of service to which they will be subjected. The quality of tire selected and purchased is especially important because the economy of tire use is determined by the cost per mile of service obtained. High-grade tires, though more expensive, will generally provide lower cost per mile service than lower grade tires.

The operators of pneumatic-tired vehicles and machines bear the major responsibility in insuring that the maximum service life of tires is obtained. The operator's observance of recommended practices for inspecting and caring for the tires, and his operation of the vehicle or machine in such a manner as to prevent damage to the tires, will result in the maximum service being received.

The repair of slightly damaged tires is feasible, particularly when the repaired tire will not be subjected to heavy loads or high speeds. The recapping of sound but worn tires can greatly extend the service life of the tires, and is becoming widly used. It is doubtful if the repair and recapping of tires can be performed economically in railroad shops bcause of the large amount of specialized equipment and the skilled personnel required. However, commercial tire shops may easily be utilized for this work.

Chairman Hutchison: The next assignment is that on storage batteries, and the report on this subject will be presented by C. F. Lewis, superintendent of work equipment of the Santa Fe.

President O'Rourke: Please do not hesitate to discuss these subjects. If you have any suggestions or constructive criticisms for these men, please give them to us.

Assignment 6—Storage Batteries, was presented by Subcommittee Chairman C. F. Lewis (Santa Fe).

Mr. Lewis: Mr. O'Rourke and gentlemen: A lead-acid storage battery is defined as an electro-chemical device for converting stored chemical energy into electrical energy and also for the converting of electrical energy back into stored chemical energy. These actions are reversible, but the battery does not store up electricity any time—it can only store chemical energy. The capacity to do so is strictly limited, depending principally upon the amounts of available active materials and the concentration of the electrolyte.

Generally speaking, the automotive-type storage battery has three major functions: (1) to provide source of current for starting, lighting and ignition; (2) to help control the voltage in the electrical system; and (3) to furnish current when the electrical demands exceed the output of the generator.

Automotive-type storage batteries usually consist of three or more cells connected in series, for which the voltage for each of these cells, when fully charged, is approximately 2.1 v with acid of about 1.280 specific gravity. Therefore, the 6-v battery usually consists of 3 acid-proof compartments and the 12-v battery consists of 6 acid-proof compartments, each containing an element composed of 2 different groups of plates assembled with separators. Each cell also contains a mixture of sulphuric acid and distilled water, called "electrolyte", in sufficient amount to cover the entire element area to a depth of approximately $\frac{3}{8}$ in above the top of the elements.

The capacities of batteries vary. Generally speaking, most automotive-type batteries of the 6-v variety are manufactured with either 39, 45, 51 or 57 plates. In other words, a 39-plate battery is composed of 3 cells, each containing 7 negative and 6 positive plates, or a total of 13 plates. The number of plates within a cell does not affect the voltage of that cell, which is approximately 2.1 v when fully charged, but it does materially affect the "service life potential" of any battery. It should be realized, however, that the total surface area of the positive and negative plates within each cell proportionally affects the "service life potential" that may be expected of a battery as much as does the number of plates within a battery.

Although a lead-acid storage battery is a complex piece of equipment, when given adequate care and proper preventive maintenance service it should generally outlast its rated "service life potential" and give trouble-free service.

CHAIRMAN HUTCHISON: The next report deals with the subject of Devices for Warning Forces of Approaching Trains. In the absence of the subcommittee chairman, it will be presented by T. H. Taylor, supervisor of maintenance of way equipment and materials of the Pennsylvania Railroad.

Assignment 7—Devices for Warning Forces of Approaching Trains, was presented by T. H. Taylor (Pennsylvania) in the absence of Subcommittee Chairman G. R. Collier (Santa Fe).

MR. TAYLOR: Mr. O'Rourke and gentlemen: A reliable system of warning gangs of approaching trains is essential to the safe and economical execution of the maintenance program.

Radio is being used successfully by some roads with the larger gangs. The gang foreman communicates via radio with the crews of radio-equipped trains as they approach the gang. This method reduces delay to trains and gangs to the limiting factor of the time necessary to set the equipment off the track.

The portable field phone is also widely used to obtain information on trains, either from an adjacent operator or from the dispatcher direct.

Audio signals, such as whistles, sirens and horns are generally used as the ultimate warning to get personnel in the clear.

One manufacturer has an electronic device now in advance stages of development that will provide 3500 ft of warning. A low-frequency current is introduced in the rails. A receiver located at the point of work picks up the signal and keeps a light burning. A train approaching the gang shorts out the current and the light goes out. This device has been field tested.

This report is presented as information.

CHAIRMAN HUTCHISON: The report to be presented now covers Care and Operation of Work Equipment in Freezing Weather. J. W. Risk, superintendent of work equipment, Canadian National Railways—who is quite familiar with freezing weather—will present this report. [Laughter]

Assignment 8—Care and Operation of Work Equipment in Freezing Weather, was presented by Subcommittee Chairman J. W. Risk (Canadian National).

MR. RISK: Mr. President, Mr. Secretary and gentlemen: Work equipment can be fully utilized during freezing weather if the equipment is prepared for winter operation, well maintained, and manned by good operators.

Of the various difficulties encountered in low temperature starting and operation of diesel and gasoline engines, the cranking problem is the most serious. When the engine is in good mechanical and electrical condition it can be started at low temperatures if

high enough cranking speed can be achieved and flammable mixture exists in the cylinders. Cranking speeds depend almost entirely on the condition of the storage battery or starting motor and the viscosity of the lubricating oil. A flammable cylinder charge depends entirely on the volatility of the fuel as indicated by its vapor pressure and distillation characteristics.

Depending upon the severity of temperature conditions, various items generally are given attention: for example; special cooling system maintenance, changing crank case oils and greases to proper winter grades, selection of proper fuels, dilution of crank case oil, installation of starting aids, and the use of materials to prevent ice formation in fuel systems, as well as providing heated shelters.

Good progress has been made and a considerable amount of development work is being done on the low-temperature problems of starting and operating work equipment. Your committee feels that these problems will be solved in a satisfactory manner.

CHAIRMAN HUTCHISON: The next assignment is that of Track Lining Equipment. This report will be summarized by W. T. Hammond, regional engineer, Lake Region, Pennsylvania Railroad.

Assignment 9—Track Lining Equipment, was presented by Subcommittee Chairman W. T. Hammond (Pennsylvania).

MR. HAMMOND: Mr. President, gentlemen: The reduction in manpower made possible by the use of multiple-tie-tamping, tie-renewal and ballast-handling equipment with track rehabilitating gangs, has made manual lining difficult and uneconomical.

To permit mechanical lining of track, with the minimum force, several types of power equipment have been developed and are now available. This report covers four types of such equipment. Basically, all of these accomplish the actual shifting of the track by means of hydraulic rams or cylinders actuated by manually or mechanically driven pumps. They differ in size, flexibility, mounting, method of propulsion, and anchoring to the roadbed.

All are available in rail-mounted single-unit models, each of which has a different method of providing visibility for the person sighting the line rail. One model is available with a crawler mount, which permits a continuously unobstructed view of both rails. One type may be had as separate power plant, either rail or off-track mounted, with separate lining rams.

CHAIRMAN HUTCHISON: The next report, Additional Types of Work Equipment Desired, has been prepared by a subcommittee headed by F. L. Etchison, chief engineer of the Western Maryland Railway, who was unable to be present this afternoon because of another meeting. His summary will be presented by Vice Chairman Munt.

Assignment 10—Additional Types of Work Equipment Desired, was presented by A. W. Munt (Canadian Pacific) in the absence of Subcommittee Chairman F L. Etchison (Western Maryland).

MR. MUNT: Mr. O'Rourke and gentlemen: Although there are many machines now available for performing a wide variety of maintenance of way work, there are still a large number of maintenance tasks that are being done manually or with hand tools.

Maintenance officers of principal railroads have been contacted and the consensus of replies indicates a need for the following equipment:

1. More efficient equipment for distributing and picking up material. If possible, this equipment should be able to work either on track or off track, as conditions require.

2. Equipment to apply and remove rail anchors. There are at present many different

kinds of rail anchors in use. There is no machinery available for applying or removing these anchors.

3. Equipment to fill old spike holes, either by setting and driving precut wood plugs, or by handling and applying some other suitable material.

4. Equipment to handle and apply rail joints, including the application of grease or other desirable materials at the ends of the rails, and the application of and tightening of all bolts.

5. Off-track equipment for handling, setting, and driving track spikes.

6. Equipment to unload cross ties economically from gondolas, flats or other standard cars, and distribute them as required along the roadbed close to the location where they will be inserted in the track.

7. Off-track tie renewal equipment.

8. Equipment for straightening and spacing cross ties uniformly. This equipment to be used primarily in connection with tie renewal program and/or surfacing.

9. Equipment to distribute ballast economically and efficiently when unloading from cars.

10. Equipment to clean and shape ditches in close cuts where clearance is insufficient to accommodate present ditching and grading equipment.

11. Equipment to sweep and lubricate switches in interlocking plants and large classification yards.

12. Equipment to lower track more economically.

13. A four-tool, multiple, off-track spot tamper operated by one man.

14. For use by bridge forces, a small portable apparatus for pulling drift bolts, stringer bolts and boat spikes.

15. Equipment to renew economically bridge ties and the caps and stringers of timber trestles.

16. Equipment for use in jacking culvert pipe through large fills.

The development of new equipment is progressing so rapidly that some of the needs outlined in this report will be fulfilled in the immediate future. Continually, changing work methods will create the need for additional equipment.

This is a final report, submitted as information.

CHAIRMAN HUTCHISON: The last report of this committee is on the subject of Off-Track Trailers for Housing Maintenance Forces. It will be presented by S. E. Haines, Port Facilities Engineer, Reading Company.

Assignment 11—Off-Track Trailers for Housing Maintenance Forces, was presented by Subcommittee Chairman S. E. Haines (Reading).

MR. HAINES: Mr. President and gentlemen: This report was written to be used as a guide and reference for those railroads considering off-track trailers for housing maintenance forces. The committee desired that the advantages and disadvantages of going from camp cars to house trailers be listed. Naturally, operating conditions vary from railroad to railroad and from state to state, and the advantages will vary accordingly.

One manufacturer requested that a check list be included in the report, so that competing manufacturers would bid on the same items. His suggestion was considered worthy and such a check list has been provided for your use. It begins with the body length of the trailer and ends with exhaust and ventilating fans. Between these two items are 46 others.

Truck length and trailer length are very important. For instance, if a truck 25 ft long were to pull a trailer 25 ft long in a state permitting maximum length of truck

plus trailer of only 45 ft, the driver would be arrested. Every time this combination was to be moved in this state a permit would have to be obtained. Thus, one of the major advantages which trailers have, namely, flexibility, would be lost.

The report is aimed at showing you how to avoid such pitfalls. Written descriptions, diagrams, and pictures are included in the report to show you what others have already done successfully. It is the committee's hope that by the use of this report railroaders will avoid making costly errors and will obtain satisfactory, comfortable, and economical quarters for their men.

Chairman Hutchison: Gentlemen, if you have any questions on these reports, our subcommittee chairmen will attempt to answer them.

If not, Mr. O'Rourke, this completes the report of this committee, and also my term as chairman. Before taking leave of the podium, I would like personally to compliment the members of this committee for their loyal support during my tenure as chairman. The records will show that these men have produced a total of 24 reports during the past 3 years, and a total of 83 reports during the last 10 years, which represents a total of 522 pages in the Proceedings. All of this is mentioned merely to indicate that the men on Committee 27 are real workers.

I would also like to announce, with deep regret, the recent passing of Mr. Ernie Cloutier, Supervisor of Maintenance Equipment of the New York Central Railroad, who was a highly respected member of this committee.

In closing, I would like to introduce the incoming chairman, Mr. A. W. Munt, supervisor of work equipment of the Canadian Pacific Railway, and Mr. F. L. Horn, engineer of track of The Terminal Railroad Association of St. Louis, who has been appointed secretary of this committee. Mr. Munt and Mr. Horn, will you please rise? [Applause]

I'm sorry I can not introduce our new vice chairman, Mr. S. H. Knight, who is fleet manager of the Northern Pacific Railway. He was unable to be on hand today because of another commitment.

President O'Rourke: Mr. Hutchison, your committee continues to make many valuable reports to the Association, keeping us currently up to date as to the developments in power tools and machines so essential to the economical and effective carrying out of our work. The Association is deeply indebted to you and members of your committee for another fine series of reports, which reflect again the able direction of the committee work under your chairmanship for the past three years.

We welcome, as the new chairman of Committee 27, Mr. A. W. Munt, supervisor of work equipment, Canadian Pacific, and as your new vice chairman, Mr. S. H. Knight, fleet manager, Northern Pacific, who is not here. We have every assurance that under these new committee officers, the work of Committee 27 will continue on the high plane of the past.

Your committee is now excused with the thanks of the Association. [Applause]

From the subject of work equipment and roadway machines, we now turn to the all-important matter of railway labor, and will next hear the report of our Committee 22—Economics of Railway Labor. The chairman of this committee is Mr. D. E. Rudisill, engineer—maintenance of way and structures, Pennsylvania Railroad, Philadelphia. I shall be glad if Mr. Rudisill and members of his committee will please come to the platform at this time, and present their report.

Mr. Rudisill, the floor is yours.

Discussion on Economics of Railway Labor

[For report, see pp. 397–431.]

[President G. M. O'Rourke presiding.]

Chairman D. E. Rudisill (Pennsylvania): Mr. President, members of the AREA, and guests: It is with regret that Committee 22 takes cognizance of the death of one of its members, Mr. H. C. Archibald, assistant chief engineer, Boston & Maine Railroad, who passed away since our last convention. A memoir in his honor is being prepared, and will be published in the convention presentation of Committee 22 in the 1956 Proceedings.

MEMOIR

Henry Cameron Archibald

Henry Cameron Archibald, retired assistant chief engineer of the Boston and Maine Railroad, died on August 5, 1955, at Boston, Mass. Mr. Archibald was born on July 26, 1891, at Everett, Mass., was graduated in civil engineering, Summa Cum Laude, from Tufts College, and in 1915 entered railway service as a structural draftsman with the Boston and Maine. From July 1917 to October 1919 he was in the Armed Forces, serving as 2nd Lieutenant with the 71st Artillery, AEF, in France. Following the close of hostilities he resumed service with the Boston and Maine, subsequently holding the positions of supervisor of bridges and buildings, assistant division engineer, division engineer, engineer of track and assistant to the chief engineer. He was assistant chief engineer from 1952 until his retirement in 1955.

Mr. Archibald joined the AREA in 1928, and after 27 years of faithful and fruitful service, was made a Life Member in 1955. He became a member of Committee 22—Economics of Railway Labor, in 1949 and of the Special Committee on Continuous Welded Rail, in 1951. He served with distinction until his death on both committees. As a member of Committee 22 he was chairman of several subcommittees for which he presented comprehensive and excellent reports. In his passing the AREA has lost an able worker and a respected friend and associate.

Mr. Archibald is survived by his wife, Helen Strong Archibald, to whom he was married on June 20, 1923, two sons, Paul and Ralph S., a daughter, Mrs. Eleanor A. Schribner, and two grandchildren. To them the members of Committee 22 and the AREA express their sincere and deeply felt sympathies.

Committee 22 has seven subjects under assignment, on five of which reports will be made at this convention. Four of these are final reports, submitted as information.

The full report of Committee 22 has been published in Bulletin 526, and is to be found on page 397 and succeeding pages. Following the reports on our various assignments we will have an address on a subject which should be of interest to all railroaders, by a well qualified speaker who will be introduced later.

The first assignment of Committee 22 is Revision of Manual, on which we have no report.

Assignment 2 will be presented by Subcommittee Chairman J. E. Eisemann, district engineer, Santa Fe.

Assignment 2—Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work, was presented by Subcommittee Chairman J. E. Eisemann (Santa Fe).

Mr. Eisemann: Submitted as information, this is the fourteenth report of a series on this subject, which has been reassigned annually since 1935. The current study covers

a reorganized and comprehensive system of track and roadway maintenance on the Southern Railway; previous studies have dealt with various maintenance operations on 13 other railroads in prior years.

The primary purpose of the trip Committee 22 made to the Southern Railway was for the purpose of inspecting the operation of one of the several completely mechanized combined tie renewal—surfacing gangs. The committee was also enabled to inspect the Southern Railway Company's Central Work Equipment Shop at Charlotte, N. C., and had the good fortune of observing the results of some very forward thinking on the part of the Southern Railway people.

The details of the mechanized operation are made a part of this report, as are descriptions and anticipated uses to be made of various pieces of equipment being developed by the Southern.

The entire inspection trip proved very educational, and the Southern is to be congratulated for its very real contributions to the railway track maintenance picture. They have effected labor economies that are very considerable.

Committee 22 expresses its sincere appreciation for having been given the opportunity to view this maintenance of way plant, and our thanks are herewith tendered the Southern Railway.

CHAIRMAN RUDISILL: On Assignment 3, the subcommittee chairman, N. M. Kelly, district engineer, Canadian Pacific, was not able to be present. Mr. H. W. Kellogg, engineer of track of the Chesapeake & Ohio, will give his report.

Assignment 3—Comparative Economy of Routine Track Maintenance with Limited Size Forces, and Cycle, Out-of-Face Track Maintenance with Fully Mechanized Forces, was presented by H. W. Kellogg (Chesapeake & Ohio) in the absence of Subcommittee Chairman N. M. Kelly (Canadian Pacific).

MR. KELLOGG: Mr. O'Rourke and members of the Association: This subject is an extensive one. It could be studied indefinitely, but is covered here only from the points of view of smoothing track,[1] and renewing ties, each operation in its own cycle. The comparisons are between the number of man-hours used in carrying out track smoothing and tie renewals by section forces, with lengthened territories or otherwise, and the number of man-hours used in carrying out the work during the same or changed cycle by fully mechanized "district gangs".[2]

Many economies may be realized through mechanization and organization which presently vary from day to day due to labor conditions, materials used and the ever-changing design of equipment.

Information for this report was obtained from railroads in the United States and Canada. Several railroads declined completing the questionnaire because they are short line railroads or because their systems of accounting prevent giving any reliable figures. The comparative statement of all the railroads which completed the questionnaire was prepared and from it one may note the average length of track section is 16.9 miles, with an average force of 6.4 men, indicating a trend toward the lengthening of sections due to a higher degree of mechanization than in previous years.

Some railroads use only mechanized district gangs, others both section and district gangs, while still other railroads use the section forces for smoothing track and district gangs for tie renewals. The trend, however, is toward the use of mechanized district gangs and an increased cycle for both smoothing track and track tie renewals.

[1] Spot or selective surfacing of track.

[2] Gang assigned to a division.

Points of interest mentioned in this report are that all railroads are endeavoring to lengthen the cycle of track maintenance in its various aspects and to mechanize maintenance forces to effect greater economy.

The anual tie renewal cycle in many cases has been lengthened to between 5 and 8 years. It is also noted that the smoothing cycle has been increased.

Figures obtained in preparing this report indicate that mechanized section gangs shows a slight saving over section gangs using hand tools, and that mechanized district gangs produce even greater savings. The figures given by the different railroads on smoothing varied greatly because of different climatic conditions, ballast, rail, etc., density of traffic and tonnage.

The committee has an apology to make with respect to incorrect information reported by a few railroads in reply to the questionnaire, having specific reference to tables on pages 420, 421 and 422 of Bulletin 526. Since publication of the report, the following changes have been requested by the railroads involved in the figures in column headed "Average Annual Gross Million Tons":

The Monongahela Railway Company—change 1,020* to 16.65.
Burlington Lines—change 1,016.1* to 2,941.8*.
Rutland Railroad Corporation—change 525.9 to 525.9*.
Illinois Central Railroad—change 571 to 4,970.7*.
Green Bay and Western Railway Company—change 608.4 to 608.4*.
Missouri–Kansas–Texas Lines—change 456.5 to 4.01.
AT&SF—change 6,600* to 31.
Elgin, Joliet & Eastern Railway Company—change 2,886* to 31.6.

It is unfortunate the column of figures in question contains figures for both average annual gross million tons and average annual gross million ton miles, but since we wished to indicate actual figures reported by the various railroads they were so shown.

In conclusion, it is apparent that cycle maintenance has not been fully adopted by many railroads and, therefore, nothing conclusive can be drawn from the figures given. This subject should be brought up again at a later date when more railroads have had experience with cycle maintenance. However, it appears that savings can be made from cycle maintenance by district gangs, with sections lengthened and forces decreased. The section forces should be mechanized only to economic necessity and used to perform spot work, with the fully mechanized gang doing all heavy out-of-face work.

Chairman Rudisill: Assignment 5 will be presented by Subcommittee Chairman L. A. Loggins, chief engineer, Southern Pacific Lines in Texas & Louisiana.

President O'Rourke: While Mr. Loggins is coming to the podium, I would again remind all of you that we will be very happy to accept your discussion. Is there any discussion on these subjects? Any questions to be asked?

Proceed, Mr. Loggins.

Assignment 5—Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization, was presented by Subcommittee Chairman L. A. Loggins [Texas & New Orleans].

Mr. Loggins: Mr. President and members: Your committee submits this final report covering the study of methods, equipment and organization used in the replacement of track ties.

Thirty-four railroads furnished us with information. All of these roads used section gangs to replace some of their ties. Twenty-seven report the use of extra gangs for

making renewals incident to out-of-face resurfacing work, and eight—the Santa Fe, Chesapeake & Ohio, Minneapolis, St. Paul & Sault Ste. Marie, New York Central, Southern, Southern Pacific Lines and Union Pacific report the use of special gangs, organized for the purpose, to renew some of their ties.

On practically all of these roads ties are inspected, and those to be replaced are marked by section foremen, roadmaster or track supervisor and, in most cases, are also checked by other officers. On the Illinois Central an experienced maintenance of way employee having specialized tie knowledge, and accompanied by section foreman or track supervisor, makes the inspection and marks the ties to be replaced. On the Santa Fe a tie department inspector inspects and marks those to be renewed.

Ties are handled on special tie cars on the Santa Fe, New York Central, Western Pacific and the Southern, but on most railroads ties are loaded loose in gondola cars and are unloaded by hand. A few band ties and handle by crane.

Ties are moved to the job site by work train or by local freight when available. Otherwise, they are unloaded at stations or sidings and distributed later by track car. The reports indicate substantial savings to be made by unloading ties from work train or local freight at the job site instead of unloading at stations or sidings and later distributing by track car.

The use of specially organized and equipped tie gangs on six railroads indicates the following percentages in reduction of cost from the conventional method with hand tools:

	Percent Reduction
Santa Fe	58
Boston & Maine	42
Minneapolis, St. Paul & Sault Ste. Marie	44
Southern	67
Southern Pacific Lines	36
Union Pacific	18

Gangs more completely equipped with mechanical tools produce greater savings than partially mechanized gangs.

The Lackawanna makes tie renewals on a cycle basis. It uses a highly mechanized 70-man gang for heavy tie renewals in connection with resurfacing. This gang averages replacing 700 ties per day while resurfacing 120 rails. All ties which will not last six or seven years are replaced.

The Southern uses a highly mechanized 25-man gang, including 13 laborers and necessary machine operators and supervision, to retie and resurface track. These gangs average replacing 288 ties per day while resurfacing 3800 ft of track.

Two roads report progress in replacing ties by the use of improved hand tools or equipment. The Missouri Pacific reports that, by using hand-operated tie pusher equipment with a 16-man gang replacing ties ahead of resurfacing, the production of the gang was increased by 49 percent. Southern Pacific Lines report that, by using hand-operated tie remover and tie replacer equipment with 4-man section gangs, production was increased by 53 percent.

This committee's study indicates that substantial economies are to be gained by the use of properly organized and equipped gangs to renew ties. It is believed that other roads will adopt the use of special tie gangs and equipment for renewing some of their ties, also equip section gangs with special tie tools, and develop special tie handling cars. This will take time.

It is, therefore, recommended that this report be accepted as information and this assignment be discontinued until more data become available on the subject.

President O'Rourke: It will be so accepted, Mr. Loggins.

Chairman Rudisill: Assignment 7 will be presented by Subcommittee Chairman H. J. Weccheider, engineer maintenance of way, Erie Railroad.

Assignment 7—Comparative Economy of Handling Maintenance of Way Gangs in Trucks Versus Motor Cars, Including Economical Length of Haul, Collaborating with Purchases and Stores Division, AAR, was presented by Subcommittee Chairman H. J. Weccheider (Erie).

Mr. Weccheider: Mr. President, members of the Association and guests: This is a final report, presented as information.

The subject matter covers data on the use of various types of highway vehicles used in maintenance-of-way work. The data presented include the following seven pertinent points:

1. Truck utilization data, presented in a special table.
2. Special trucks used.
3. Operation.
4. Ownership.
5. Maintenance.
6. Economy derived.
7. Advantages and disadvantages.

Forty-two of the 46 Class I railroads replying to our questionnaire use highway vehicles in one phase or another of maintenance-of-way work. The four exceptions due to geographical locations, do not have sufficient highways conveniently located to their lines.

An upward trend in the use of highway vehicles in lieu of motor cars started in 1940, with a decided increase coming in 1945. Three southern, two eastern and one western railroads have now reached 100 percent truck utilization in the following types of maintenance gangs: Extra track, large yard, district, bridge and building, water service and plumbing, signal and communications, district welding, and engineering personnel.

The use of trucks is more prevalent east of the Mississippi River than in the western regions and Canada, due to more closely paralleling highways, denser railway traffic, and climatic and geographical locations.

The table on page 426 of Bulletin 526 was compiled from the various replies to our questionnaire. It indicates the class of employes to which trucks are assigned and the percentage using trucks. This figure is based on the number of trucks in use compared with the number of gangs in each separate class. The tonnage of trucks and average number of men carried per truck are also indicated.

Briefly, the table shows the following with respect to the various classes to which trucks are assigned as a substitute for motor cars:

Miscellaneous forces, such as maintenance-of-way shop gangs, tunnel inspectors, scale inspectors, etc., are 96 percent equipped with trucks, and engineering personnel 82 percent. In the larger gangs doing out-of-face work and construction, such as district and extra track gangs, large yard gangs, bridge and building gangs, and signal and communications construction forces, the percentage using trucks in lieu of motor cars runs from 87 percent for district track gangs to 57 percent for district welding and system bridge and building gangs. Signal and communications construction gangs are 74 and

68 percent, respectively. The smaller gangs, such as regular track sections and signal maintenance forces, whose work is confined to designated sections of track involving detailed inspections and repairs, are only 10 and 18 percent, respectively, equipped with trucks.

Many of the trucks are especially equipped for the particular work done by the gang using them, some being equipped with post hole diggers, "A" frames for handling material, power winches, hydraulic lift gates, etc. This equipment could not be provided on motor cars because of its excess weight.

The economical length of haul varies with the class of employes involved, as shown in the report. Railroads having paralleling roads or highways, which cross their tracks at fairly short intervals, report that trucks can be driven to a distance of 25 yd to ½ mile from the site of the work.

The survey developed that railroads vary as to ownership or rental—84 percent owning all their own trucks.

It is the conclusion of your committee that the use of trucks in lieu of motor cars has resulted in substantial savings in various phases of maintenance-of-way work where the geographical location and traffic of a railroad warrant their use. The savings are realized principally from the reduction of unproductive work hours resulting from motor car operation, elimination of camps and equipment, and reduction in the cost of handling material to job sites. Through the use of trucks in transporting men and material in the shortest possible time, unseen economies result in restoring the railroad more quickly to active operation following derailments and washouts.

These economies can be obtained through a well-thought-out plan of organization and operation, giving careful study to each phase of maintenance work and the location involved.

H. N. Halper (Erie): In your report, Mr. Weccheider, you show the percentage of trucks. Can you tell me approximately the number of trucks used?

Mr. Weccheider: Forty-two of the 46 railroads reported using trucks. Nine of these 42 didn't give the total number of trucks used, although they did give a very good report, in separating the percentage of trucks for gangs, etc. In fact, one railroad that I have in mind (which isn't included in the total) has about 800 trucks. In other words, it is one of the largest railroad users of trucks.

But for the 33 roads which gave us definite figures, the total number of trucks in use was 6298.

Mr. Halper: Thank you, Mr. Weccheider.

President O'Rourke: Are there any other questions?

R. J. Pierce (Erie): Mr. Weccheider, did the railroads furnish any figures as to the life of their trucks by years?

Mr. Weccheider: You mean before being repaired or replaced?

Mr. Pierce: Before being replaced.

Mr. Weccheider: Practically all of the railroads reported that they make a very careful field inspection. They take into consideration the type of truck and the service, and, of course, its general condition.

A number of railroads reported they base their replacement on practically a five-year cycle. Other railroads reported a six-year cycle, while one very large railroad reported that it replaces its trucks when the repairs would figure about 75 percent of the truck value. There were other formulas given, but those mentioned are the principal ones.

President O'Rourke: Any other question? Discussion?

I guess not, Mr. Weccheider. Thank you for a good report.

Chairman Rudisill: Assignment 8 will be presented by Subcommittee Chairman P. A. Cosgrove, division engineer of the Illinois Central Railroad.

Assignment 8—Economic Size of Maintenance Force Using On or Off-Track Tampers and Renewing an Average of 100 Ties per Mile, was presented by Subcommittee Chairman P. A. Cosgrove.

Mr. Cosgrove: Replies to a questionnaire covering this subject were received from 23 railroads. These roads reported a total of 67 surfacing operations and indicated that 4 on-track-type tampers, and 2 off-track-type tampers are predominent in carrying out the out-of-face raising and tamping of track.

The figures listed on the bottom of page 430 show the average labor expense per mile involved in out-of-face surfacing operation by on-track and off-track tampers, as furnished by all of the reporting railroads.

An important item of labor expense involved results from traffic delays. The report bears out the fact that on-track tampers can be justified on railroads where the traffic delays are not too great. If the expense of traffic delays amounts to a large portion of the total labor used for these surfacing operations, it is more economical to use hand held off-track equipment.

The most economical size gang performing out-of-face surfacing, using either on-track or off-track equipment, was found to be 20 to 24 men—and they did not install cross ties during the surfacing operation.

This is a final report, submitted as information.

Question: Did the committee discover what was the breaking point where an on-track and off-track tamper could best be used? Where is the breaking point on traffic interruptions?

Mr. Cosgrove: The percentage wasn't exactly developed. It is something that everyone has to known from experience on his own individual railroad—to know whether he is losing money with on-track or off-track tamping machines.

President O'Rourke: Are there any other questions? This is certainly a controversial subject, and should develop some discussion from the floor.

If there is none, proceed, Mr. Rudisill.

Chairman Rudisill: Committee 22 considers itself fortunate to be able to offer as a special feature of its presentation, at this time, an address by a man who has devoted considerable time during the past several years to the problems connected with safety and methods for getting the necessary cooperation for better safety and work performance on the part of maintenance-of-way workers. He will address us on the subject, Better Human Relationships as a Key to Improving Maintenance of Way Work.

It gives me pleasure at this time to introduce Mr. W. E. Cornell, engineer of track of the New York, Chicago & St. Louis Railroad.

Better Human Relations as a Key to Improving Maintenance of Way Work

(How are your manners?)

By W. E. Cornell

Engineer of Track, New York, Chicago & St. Louis Railroad

Merwin Dick, commenting in the December 1955 issue of Railway Track and Structures magazine under the heading "Human Relations and the Foreman," said, "It is now more generally recognized that people work better if somebody takes the time to tell them something about the why's and wherefore's of the work they do, and also that getting a man to do his best is a science based on the need for recognition."

Many industries, such as Goodyear Tire and Rubber Company, Kroger Grocery and Baking Company, and General Motors, have given substance to the idea which Mr. Dick has so aptly phrased, and as a result much has already been accomplished both in better and more efficient work performance and in the safety of that performance; and since railroads also employ people, there appears to be no logical reason why they too cannot benefit from a similar approach to the employee performance problem.

I do not wish to try and pose as an expert in psychology and in the science of handling men because I am not so qualified, nor do I believe such expert qualification is necessary to achieve greatly improved results. I merely want to try and put into words the things you already know—the things we talk about when we discuss work performance. These are the proven practicality of getting the needed cooperation from men by the use of the principles of good leadership; the principle of good human relations or, more simply, on-the-job courtesy; not drawing-room courtesy; not the kind of courtesy we sometimes use to impress the ladies, but on-the-job man courtesy; the kind of courtesy that any man can understand and can respect you for using.

The things I say here today are not original with me. I am simply repeating the findings of men who devote their time to the business of human performance.

You sometimes hear a man say you can't teach a man to handle men because they are all different; you have to pat some on the back and you have to kick others. I'm certain the situation is not that hopeless. Certainly all men are different, but their differences in this respect fall into two main classifications, one major and one minor; the conformist class and the non-conformist class, in a ratio of about 19 to 1.

There is little if any fundamental difference between us and the fellow working out on the job. I would guess that most of the men here today have at one time or another performed manual labor for pay, and you know what your reactions were to the boss's attitude at that time, and I'm quite sure they haven't changed greatly since; certainly they haven't changed simply because you put on a necktie to come to work.

The late Dale Carnegie said that 95 percent of all people respond favorably to the principles of good human relations, and for the other 5 percent you could use a baseball bat. Mr. Carnegie did not qualify that statement by saying that good human relations applies only to men who come to work wearing neckties.

Granted that you figuratively have to kick 1 out of 20 men, is that any logical reason why you should lose the improved performance of 19 simply because you may find 1 who does not fit the pattern?

Railroad progress and development through research have been remarkable, and it has been said that only because of this progress and development are the railroads able to operate today. But that progress was largely in the field of development of materials,

machines, methods and organization, and I am not overlooking the very excellent work that has been done by Committee 22. But again, Committee 22 deals primarily with methods and organization and not with the employee as an individual, his reactions and attitudes, and the means of stimulating his interest and desire for better performance.

It is interesting to note that while almost 50 percent of total railroad operating revenue is spent for labor, the greater emphasis on improvement in railroad operation has been on machines and materials which, together with fuels, take less than 25 percent of the operating revenues. From these figures it can readily be seen that a very small improvement in the efficiency of labor performance will amount to dollars very quickly.

Recent University of Michigan studies indicate that the average United States worker produces at only about 41 percent of his capacity. It would, therefore, appear there is much room for improvement in the efficiency of the individual without endangering his health, and I believe it has been fairly well accepted by doctors that, whether mentally or physically employed, the stress and strain on the individual is generally very closely related to his attitude toward his job and the people with and/or for whom he works, and not necessarily with the energy expended.

I'm sure we have all seen poor attitudes and subsequent unsatisfactory performances result from discourtesy in the form of sarcasm and ridicule. A man will forget many other unpleasant things about his job a lot quicker than he will forget or forgive being ridiculed or humiliated by his boss.

On my railroad a review of the records of 45 track foreman, almost all of whom I have known personally for 15 or more years, indicated a very definite relationship between good safety performance and good work performance, and the manner in which the foreman treated his men. Those who have the best performance records are also known for their fairness and consideration in handling their men.

Another good example of good human relations at work has been the progress made by our safety men. We all know that much of their earlier efforts met with considerable resistance, both active and passive. While they may have had top management's blessing, they still had to get the cooperation of the local supervision and the men in the field. Whether by voluntary choice or as an expediency, to overcome the resistance they, in most cases, approached their problem on the basis of the importance of each individual; they asked for and received his cooperation.

It is axiomatic that nothing can be accomplished satisfactorily by a group without cooperation of some sort. In broad terms there are probably two methods of obtaining cooperation. One of these can be classed under the heading of fear—fear of physical or mental abuse, or economic fear, fear of loss of job. And the other and by far the most satisfactorily effective way to obtain necessary cooperation, is by principles of good leadership. It has been well established by studies and by practical observation there can easily be a difference of as much as 50 percent or more in the results between these methods of getting cooperation, depending on how closely the fear-driven cooperation can be supervised. If any one has that much supervision, they should lay off the men and put the supervision to work.

The men themselves are aware of the relative value of these methods because as a group they are accurate judges of the qualities that good bosses should possess, and they are equally alert in their appraisal of unsatisfactory bosses. The ability of the men to judge the qualification of the boss was brought out very well by studies conducted by the University of Michigan human relations program. These studies found that more employees, working under supervisors whom the management considered immediately promotable, saw their supervisors as "leaders of men", "reasonable in what they expect",

and "likable", as compared to the questionable or unsatisfactory supervisors whom the men said were "drivers", "bossy", and "quick to criticise."

These findings were consistent with another study among railroad workers, which found that more men in high-producing section gangs felt their foreman reacted in an "understanding", "non-disciplinary way", when they did a bad job; while the men in the low-producing gangs felt their foreman "bawled" them out or made them do it over without explanation.

In this business of safety and good work performance we must necessarily work with people. The application of the principles of good leadership is not an exact science, and it is not easy to successfully apply the principles. The same blueprint will not fit all cases exactly alike. In many instances we must translate a vague awareness into something understandable and usable; and to do so we must allow a little leeway but perhaps not quite as much as the young lady who, while madly in love with the young man, said she would not marry him until he had saved $5,000. About 4 months later she asked him how he was making out. "Right now," he said, "I got 18 bucks." And she said, "that's near enough." We of course should not settle for 18 bucks in this business of good leadership, but she was a smart young lady and I think, likewise, 18 bucks is 18 bucks, and we've got to start some place.

No doubt when working with people there are times when our patience and our forebearance are just a little stretched. And for this, in closing, I would like to quote, as a creed to temper our feelings, a little prayer which I am sure most of you have heard many times before.

I believe this prayer was first given by Dr. Reinhold Niebuhr of Union Theological Seminary of New York. He said:

"God grant me the serenity to accept the things I cannot change, the courage to change the things I can, and the wisdom to know the difference."

Chairman Rudisill: Thank you, Mr. Cornell. It has been the good fortune of Committee 22 in the past to have been able to present convention features on various subjects, with some excellent speakers. I am sure all of you will agree with me that Mr. Cornell's address has well maintained this tradition, and on behalf of Committee 22, I wish to thank him for his most interesting and timely address.

Mr. President, this completes our report.

President O'Rourke: Mr. Rudisill, it is evident that our committee—and I say that advisedly, because I happen to be the dean of his committee in years of service, and age; I'm the oldest man on it—has had an active year during your first year as chairman, and I congratulate you upon the work which has been done, as reflected in the reports which have been presented to this convention.

I want to add my thanks to yours, to Mr. Cornell, for the stimulating and thought-provoking message which he has brought to us on the value of better human relations within our industry, and especially within the engineering and maintenance-of-way departments. Unquestionably, both the railroads and we, as an Association, have given much less than the desirable amount of attention to this most important matter. So we are indebted to Committee 22 and to Mr. Cornell for making this subject a part of our convention program.

Mr. Rudisill, your committee is now excused, with the thanks of the Association. [Applause]

Our last report today will be made by the Special Committee on Continuous Welded Rail. The chairman of this committee is C. E. Weller, division engineer, Illinois Central

Railroad, at Jackson, Tenn. Without further remarks, due to the lateness of the hour, may I ask Chairman Weller and the members of his committee to take their places at the speaker's table?

When this committee's report is completed, there will be a general exodus, I know, because it's going to be late, and everyone will hurry out of here. So, I just want to tell you now that tomorrow's session will be resumed in the Grand Ballroom, at 9 am. We are starting at 9 o'clock because we have a number of important reports to be made, and also, tomorrow's session will include our Closing Business Session, with the installation of officers for the coming year.

Mr. Weller, the microphone is yours.

Discussion on Continuous Welded Rail

[For report, see pp. 775–781.]

[President G. M. O'Rourke presiding.]

Chairman C. E. Weller (Illinois Central): Mr. President, members and guests of the Association: The year 1955 was one of real growth and progress for continuous welded rail. The introduction of the electric weld into this country gave us a second method of welding. During the year, over 270 miles of continuous welded rail were laid on 9 different roads. This compares with approximately 88 miles in 1954, and is an increase of over 300 percent.

This growth and progress should continue through 1956. It is probable that over 400 miles of continuous welded rail will be laid on about 14 different roads this year.

During the past year your committee has had several studies in progress, and the Subcommittee on Fabrication has a report to make. William Nuetzel, division engineer, Baltimore & Ohio Chicago Terminal Railroad, subcommittee chairman, will present the report.

Assignment 1—Fabrication, was presented by Subcommittee Chairman William Nuetzel (Baltimore & Ohio Chicago Terminal).

Mr. Nuetzel: Mr. President, Mr. Chairman, members and guests: The Subcommittee on Fabrication has submitted its first report on the electric flash butt-weld method of welding rail. This report is intentionally general in character and scope as it was felt that relatively rapid advance would be made in the techniques involved in the use of this method.

The flash welding of approximately 70 miles of track in 1955 indicates that the next report will contain more detail information as well as what we hope will be reliable data in connection with costs.

This committee is also carrying forward a continuing investigation of the oxyacetylene process.

Chairman Weller: Thank you, Mr. Nuetzel.

One of the fine things that has happened to continuous welded rail is the production of a picture telling its story. We believe this committee can serve its purpose best by giving you the opportunity of viewing it. It is entitled "Welded Rail on the Santa Fe." Mr. R. H. Beeder, assistant chief engineer, system, Santa Fe, will give us the presentation and comments.

[The film was then shown].

President O'Rourke: Thank you, Mr. Beeder.

CHAIRMAN WELLER: Mr. Beeder, the Association has already thanked you officially. Our committee would like to congratulate you and your railroad for this very fine picture. We are deeply grateful, and wish to thank you for this presentation and your comments.

Mr. President, that concludes our report.

PRESIDENT O'ROURKE: Thank you, Mr. Weller.

Your committee is excused with the thanks of the Association. [Applause]

[The meeting recessed at 6:17 o'clock.]

Morning Session—March 15, 1956

[The meeting reconvened at 9 o'clock, President O'Rourke presiding.]

PRESIDENT O'ROURKE: We will now begin the final technical session of our Fifty-fifth Annual Meeting. Will the meeting please come to order.

We have adopted a different speaker's table arrangement for this morning's session, in place of one long speaker's table, as in the past, in order to more nearly centralize reporting committees in the room, and to provide places for all committee members up in front, rather than to ask some to sit at the "bobtail" overflow table which we have provided in previous year.

Under the new setup, it is requested that the chairman, vice chairman and committee secretary take their places at the high-level table immediately to my left, and that all reporting subcommittee chairmen likewise take places at the high-level table, as near to the podium as possible, in order to minimize their travel time to the podium when called upon. Other members of committees will be asked to fill out vacant places at the high-level table, and then to occupy the available places at the speakers' tables in front. I hope that this new arrangement works out to our advantage, and that you will like it.

The first of our committees to report this morning is our Committee 3—Ties, of which L. C. Collister, manager Tie and Timber Treating Department, System, of the Santa Fe, is chairman. I shall be pleased if Mr. Collister and the other members of his committee will come to the platform on the basis which I have already explained, and make their presentation at this time.

Again—and applying to our entire morning session—we will welcome comments and criticism from the floor on any of the reports presented, and I hope that you will not hesitate to use the radio microphones which have been provided for that purpose.

Mr. Collister, will you proceed with your presentation?

Discussion on Ties

[For report, see page 441.]

[President G. M. O'Rourke presiding.]

CHAIRMAN L. C. COLLISTER (Santa Fe): Mr. President, members of the Association, distinguished guests: The report of Committee 3 is printed on page 441 of Bulletin 526. We are reporting on three of the eight assignments. The first, Subcommittee 3—Substitutes for Wood Ties, will be presented by L. P. Drew, assistant chief engineer of the Union Pacific Railroad, and chairman of that committee.

Assignment 3—Substitutes for Wood Ties, was presented by Subcommittee Chairman L. P. Drew (Union Pacific).

MR. DREW: Mr. President and members of the Association: It has been previously reported by this committee that to date no tie of material other than wood has proven

satisfactory. Most recent evidence bears out this statement, although there is still considerable interest shown in the development of reinforced concrete ties, similar to the reinforced concrete sleepers used in various European countries.

So far nothing of interest has been developed in the use of plastics as a substitute for wooden ties, but this committee is watching this phase.

While no formal report is being made, your committee is still holding open files so that any development of interest can be reported to the Association.

Chairman Collister: The report of Subcommittee 4—Tie Renewals and Costs Per Mile of Maintained Track, will be presented by Subcommittee Chairman L. W. Kistler, tie and timber agent, St. Louis–San Francisco Railway.

Assignment 4—Tie Renewals and Costs Per Mile of Maintained Track, was presented by Subcommittee Chairman L. W. Kistler (Frisco).

Mr. Kistler: Mr. President, members and guests: The report of the committee on this assignment was published in Bulletin 523 for June–July 1955.

There are many interesting aspects of the annual tie renewal statistics for 1954. The most important one is that only 22,902,197 new wood cross ties were inserted in maintenance, a reduction of 6,507,550 from 1953. This represents a 22.1 percent decline.

On the basis of ties per mile, the reduction was from 90 to 70, and the 5-year average of ties laid in replacement per mile of track reached an all-time low of 86. Based on 86 ties per mile, the computed service life would be approximately 35 years.

Of the 125 Class I railroads listed in the tables, only two reported over 1,000,000 ties renewed for the year. Twenty-three roads inserted less than 50 ties per mile in 1954, but most of these were the shorter lines—only 5 of them maintaining 3,000 miles or more of track. However, several railroads installed less than half as many ties in 1954 as they did in 1953.

Several factors contributed to these reductions.

For one thing, the year 1954 was one of adjustment for the railroads and they became deeply inventory conscious, which not only affected their purchases but also their cross tie insertions. Another very important factor was the reduced traffic or earnings which caused more selective renewals or maintenance. Results of the three regions most affected by this were as follows:

Reduction in Cross Tie Renewals as Related to Traffic

	Cross Tie Renewals	*Equated Gross Ton Miles*
Central Eastern Region	41 percent	12.3 percent
Great Lakes Region	32 "	8.7 "
Pocahontas Region	31 "	7.9 "
United States (125 railroads)	22 "	7.5 "

Note the reductions are in the same order.

While the exact number is indeterminable, still it is well known that many thousands of reclaimed or second-hand ties were laid in renewals in 1954, but which, due to accounting practices on most railroads, are not reported in these statistics. It is thought that on some railroads the effect is considerable and tends to distort the other relative data.

There was not much change in the average cost of ties in 1954, except in the Northwestern Region where it increased 32 cents per tie. For the entire United States the average cost declined 6 cents each, to $3.30 per tie.

The Interstate Commerce Commission reclassification of railroads, effective January 1, 1956, will reduce the number of Class I railroads, and thus the number reporting cross tie statistics to the Bureau of Railway Economics. It is impossible as yet to tell just how this will affect the continuity of these statistics with respect to the various regions. Naturally, it will not affect them for any individual railroad continuing to report data for their lines.

CHAIRMAN COLLISTER: Thank you, Mr. Kistler.

Subcommittee 5 has under study the methods of retarding the splitting and mechanical wear of ties, including stabilization of wood, collaborating with Committee 5 and the National Lumber Manufacturers Association.

Mr. G. M. Magee, director of engineering research, AAR, has kindly consented to review the NLMA research work.

Assignment 5—Methods of Retarding the Splitting and the Mechanical Wear of Ties, Including Stabilization of Wood, Collaborating with Committee 5, and NLMA, was presented by G. M. Magee (AAR).

Cooperative Research on Cross Ties Between NLMA and AAR

By G. M. Magee
Director of Engineering Research, Engineering Division, AAR

The chairman of the Tie committee has asked me again to give you a progress report on the research accomplished during the past year at the TECO Laboratory in Washington on "Prolonging the Service Life of Cross Ties." This work is being conducted under a cooperative agreement between our Association and the National Lumber Manufacturers Association, with representatives from both associations.

To review past developments briefly, the first phase of this work was to examine cross ties removed from track in various sections of the United States and examine the deteriorated area under the tie plate and the general condition of the tie, particularly with respect to the reasons for renewal. It was concluded from this survey and from laboratory examination of ties removed, that decay was of little consequence in causing renewal of treated ties and that the principal factors dictating renewal were abrasion from the tie plate and checking and splitting. Laboratory examination of the deteriorated areas under the tie plate brought to light another interesting development: namely, that there was a deterioration of cellulose in the wood fibers due to chemical attack from the iron corrosion products from the tie plate and spikes. It was decided, therefore, to concentrate work on reduction of checking and splitting and on means of improving the resistance of the wood in the tie plate area to abrasion and chemical attack.

Most of the checking and splitting of ties was found to develop during their seasoning period in the tie yard. Extensive tests were carried out in an effort to utilize end-coating materials to reduce this checking and splitting. It was concluded, however, that any end coating which would retard the dissipation of the moisture from the tie sufficiently to be effective in controlling checking and splitting would introduce the hazard of decay before the tie was dried sufficiently for treatment. Work was begun, therefore, on a method of drying and seasoning the green tie which would accomplish the drying without permitting checking and splitting cracks to develop. After a thorough search of patents and literature and extensive laboratory investigation, the idea for the combined seasoning and treating process developed. In this process a chemical, glycol, is added to

the treating mixture for the purpose of softening and toughening the fibers in the outer portion of the tie so they will not rupture from the stresses set up in the drying process.

I have stated previously the various obstacles that arose in the development of this process. These included primarily a need for reducing the cost of the treatment so that it would be compatible with the benefits obtained. To accomplish this it was found that a low cost residue glycol could be utilized, and a technique was developed so the amount of glycol required per tie was minimized. The process was developed to the point that last year the Pennsylvania Railroad and the Illinois Central Railroad arranged for the treatment of 1500 and 500 green mixed oak ties respectively by the Koppers Company at its treating plant at Orrville. The TECO staff was present during this treatment and made detailed observations of all phases of the drying and treating procedure. Following the treatment, the ties were installed in heavy-duty main-line track by these two railroads for observation of their service performance. A number of the treated ties were taken to the TECO Laboratory for further laboratory examination, primarily by rolling-load tests to determine whether the strength of the tie to repeated loading from the tie plate had been appreciably affected. In addition, static bending tests were made on a number of ties treated by the combined seasoning and treating process and compared with ties treated by the conventional treating process. These static tests showed that there had been some reduction in the flexural strength of the tie, but service tests of the tie and the service performance of these ties will determine whether this reduction in strength has been sufficient to be a factor in their useable life in track. It is the opinion of the Administration Committee directing this research that the combined seasoning and treating process is definitely in the experimental stages and further work and service experience is necessary before conclusions can be reached as to the effectiveness of this process or its economy. However, the advantages are so important if they are attainable that the committee believes the work should be continued until its economies and effectiveness are definitely determined one way or the other.

Other interesting phases of the work that has been conducted during the past year are the outdoor exposure test of tie-coating materials at the TECO Laboratory and laboratory work on means of toughening the tie plate area and increasing its resistance to chemical deterioration. Many different types of tie coatings have been included in this exposure test. Even for the best coatings included in the test it is indicated that the coatings will not be effective for a period of much more than 5 or 6 years. Work is being conducted, therefore, in an effort to find a coating material which will be effective for a considerably longer period.

In the work on toughening the tie plate area, some benefits have been indicated by certain resins that have been tried, but none has been found so far which indicates sufficient benefit and practicability for use with respect to cost to be considered satisfactory. Accordingly, this work is being continued in a search and trial of other types of chemicals for this purpose.

President O'Rourke: Thank you, Mr. Magee.

Chairman Collister: Thank you, Mr. Magee. The Association greatly appreciates the time and effort that you took to prepare and present this report.

Mr. President, that concludes the formal report of Committee 3. However, if you will bear with us while the members of the panel take their places, we will continue with a panel discussion.

Panel Discussion on Cross Ties

Chairman L. C. Collister (acting as moderator): It was with a deep feeling of pride and honor that Committee 3 accepted the invitation of President O'Rourke to present a panel discussion on ties. We feel that this discussion will be of interest to you, especially because the wooden cross tie, a humble stick of wood, still remains the foundation on which our industry is run, and, as you so well know, is the cause of the largest expenditure for railway maintenance.

Because of the limited amount of time allotted, we would like to confine our discussion to the importance of adherence to specifications for ties; the advantages and disadvantages of acceptance inspections; the possibilities for greater use of timber stands, including hardwoods, without disadvantage to users; and anti-splitting devices.

You will note that we are basing our discussion this morning primarily on the production phase of ties, and while we will direct our thinking that way, a lot of the questions, of course, will, because of their relationship to the user phase, deal with the user phase. The ideas to be expressed here are not necessarily the ideas of any given railroad or of the AREA. Most of the members of this panel are men with whom you are well acquainted, but for those of you who do not know them, let me now present Mr. H. R. Duncan, superintendent of timber preservation, Chicago, Burlington & Quincy Railroad, Mr. L. W. Kistler, tie and timber agent, St. Louis–San Francisco Railway, Mr. P. D. Brentlinger, forester, Pennsylvania Railroad, Mr. C. S. Burt, assistant to vice president purchases and stores, Illinois Central Railroad and Mr. L. P. Drew, assistant chief engineer, Union Pacific Railroad.

I would like to direct the first question to Mr. Brentlinger: **What are the advantages and disadvantages of acceptance inspections performed after the seasoning period as compared to acceptance inspections before seasoning—that is, dry inspection versus green inspection?**

P. D. Brentlinger (Pennsylvania): The advantage in the inspection of the dry tie is that the inspector is able to see pronounced defects that develop during the seasoning period. These defects are not always visible at the green stage, but they are more visible and pronounced after a year's seasoning.

The disadvantage in the inspection of dry ties is that the company that is buying the ties has very little control over the proper stacking, spacing and the separation of species in the stack.

Chairman Collister: Mr. Burt, how many years of service may we expect from a new, treated, first-quality, main-track cross tie, under most unfavorable conditions?

C. S. Burt (Illinois Central): That's a good question, but a little difficult to answer. I think any estimate of the service life of ties should be made only after a most careful evaluation of all of the determining factors, such as weight of rail, ballast, drainage, speed and density of traffic, curves, and, probably more important than all, changing climatic conditions. It is very important to know as much as possible about all of those conditions before we attempt to compare the performance of ties on one railroad with those on another. All of those factors are vital, and they vary a great deal in different areas.

In my humble opinion, ties in main track, under most unfavorable conditions, should last from 10 to 18 years; under more average conditions, 18 to 25 years; under the most favorable conditions, from 25 to 35 years.

Chairman Collister: Mr. Kistler, what percentage of ties with damaging end splits will justify the cost of the application of dowels, S or C irons, or artificial seasoning?

L. W. Kistler (Frisco): That sounds like the 5-part, $64,000 question. I wish I knew all the answers. I think it is a question which each individual railroad must answer for itself. One of the things which must be taken into consideration is the use or outlet we have for the ties which are split. Incidentally, I wish our moderator had left the word "damaging" out of the question, because it is generally conceded that all splits are damaging.

Some of the uses for split ties are for cribbing or retaining walls, fence posts, foundation blocks, sills, and even in temporary tracks or tracks which it is known will soon be abandoned.

Other factors concern the use of the tie itself—that is, the density of traffic; the vibration to which it might be subjected, which would accentuate the split; whether it is to be used in territories having long summers, high temperatures, and high humidity; or whether it will be used in areas of short summers, low temperatures, and low humidity. Another factor, of course, is that in some areas the ties are subjected to severe freezing in the winter, with the formation of ice, which naturally tends to further accentuate splits.

To sum up, it's an individual problem which each individual railroad must assess and determine for itself.

Chairman Collister: Mr. Duncan, why are railroads expected to accept overlength ties when they know that various ballast-cleaning machinery will not clear these overlength ties?

H. R. Duncan (Burlington Lines): Years ago, before we bored and adzed ties, and before we had the type of work equipment we now have to carry on our work on tracks, very little attention was paid to the length of ties. Our AREA specifications had a tolerance 1 in shorter and 2 in longer in length than specified. However, generally, the adherence to that was not too good, but we were not too much concerned about it. Later, we found that we received a great many ties that we couldn't get through the boring and adzing plants. They were too long. We found that irregular ties interfered with the use of some of the ballast machines, and other machines used.

Some years ago our specification was changed so we would permit no ties under the specified length. They could be 1 in over in length. Since that time we have had some difficulty securing all the ties we have wanted with the exact tolerance. However, generally, there has been quite a definite improvement. While we sometimes get some that are not within our present specification, the majority of them are.

I think the only reason that any of them are offered is because some railroads, perhaps, don't have the type of equipment that makes it necessary to adhere to that specification, and oftentimes, then, the producers expect us all to accept those ties. It can't be done.

As I said, there has been improvement, and I expect that there will be further improvement, so that ties will all be satisfactory to us. I know some of the problems that the producers have, but if they will start out in the woods, where they cut their ties, and try to get away from as much yard work as possible, I think they can give ties as they should be.

Chairman Collister: Mr. Drew, why is face width in excess of tie plate width necessary?

L. P. Drew (Union Pacific): As you all know, a railroad cross tie is a structural member, and therefore is subjected to excessive stresses due to the loads. As such, it should be designed to resist those stresses to the best of its ability.

If the width of the tie is in excess of the tie plate area, then there is more area on the top of the tie, under the plate, to absorb your stress; thus you reduce the tendency to crush. On the other hand, if the face width of the tie is less than the width of the plate, it reduces the area under the plate and increases the tendency to crush the fibers of the wood under the plate edges. This induces decay and shortens the life of the ties. It also increases the tendency of the tie to roll in the ballast.

Chairman Collister: Mr. Burt, taking into consideration our present transportation, handling and track labor rates, is it practical to purchase second quality ties for use in branch lines, side tracks and yards?

Mr. Burt: In my opinion, Mr. Moderator, ties of second quality should not be used in branch lines, yards or sidings. To do so does not provide the greatest return on the investment, dollar-wise. It has been our experience that many ties in these tracks fail because of decay; accordingly, I believe that ties of the best quality should be used in these places. Very probably, they should be given greater protection against decay through heavier retention of preservations.

Chairman Collister: Mr. Brentlinger, is it economical to use anti-splitting devices, and to what limit should they be used?

Mr. Brentlinger: I believe everyone is familiar with the fact that if there are no anti-splitting devices in a tie that is split in track, the split will continue.

There are two ways commonly used today for applying anti-splitting irons—inspection of ties and the application of irons to the ends of ties that have incipient checks or splits, or 100 percent application of irons on the basis that the tie may split in track.

Once the tie is in track, there is no economical way to close the split. Therefore, anti-splitting iron should be used on those ties that show incipient checks, or in species which we know are very likely to check.

Chairman Collister: Mr. Kistler, why should minimum width, thickness and length be adhered to?

Mr. Kistler: Mr. Moderator, Mr. Duncan and Mr. Drew have already touched on this same subject. The cross tie is a vital structural member of the track, and it individually transmits the loads to the composite roadbed. Under present conditions of heavy-tonnage, high-speed trains, if the smooth-riding characteristics of the track are to be maintained, which are so important, then it is equally important that each tie transmits the loads to the roadbed as uniformly as possible. To do this means that the tie must have nearly equal bearing areas, both at the bottom of the tie and also on the sides, for there is considerably more stress on the sides of the tie than I think we sometimes realize, particularly those of us who are not actually engaged in the use of the tie itself.

There is another factor, and that is that with the increasing trend toward mechanized maintenance of track, it is just more or less automatically understood that the more uniform the ties are in size, the closer tolerance to which these machines can work, and the closer tolerance to which they can work, the more efficient is their performance.

Chairman Collister: Mr. Duncan, since many hardwoods will damage before they are sufficiently dry to prevent additional seasoning checks developing after treatment, and the tie is in track, is it economical to employ artificial methods of seasoning?

Mr. Duncan: That is a subject on which there is a considerable difference of opinion, even in our own committee.

If hardwood ties can be purchased, shipped, handled and separated by species, and only one species treated in a charge after satisfactory air seasoning, and before they are damaged by decay, satisfactory results can be secured. However, if mixed species are stored in one seasoning pile and treated in the same charge, we are frequently confronted with the problem of waiting until all the ties are air seasoned sufficiently to permit treatment, and some of the species that season more rapidly may be decayed.

On the other hand, if we attempt to treat them before they are all properly air seasoned, then we may not secure satisfactory penetration of the preservatives, and we can expect further checking and splitting after treatment.

Some of us are of the opinion that it is economical to incise hardwood ties when they are green. In our opinion, this results in less severe checks and splits, but results in a greater number of smaller checks and splits in some species, but not all. It improves the penetration of the preservatives.

Others feel that it is economical to employ other artificial methods of seasoning, such as vapor drying, controlled air seasoning, and others. I have observed a considerable amount of work that has been done by artificial seasoning by others, and we have had rather costly and unsatisfactory experience of our own. While I may at some later date be convinced that some method of artificial seasoning of hardwood is satisfactory and economical; at present it is my very firm conviction that the only satisfactory way to process hardwood ties is by separating them by species, thoroughly air seasoning them, holding out those that are severely split, doweling them, boring and adzing them, and then treating them with a sufficient quantity of approved preservatives.

Chairman Collister: You don't mind if I say a word or two in favor of vapor drying?

Mr. Duncan: No. There are several other fellows who want to talk on that, too.

Chairman Collister: With the low-grade swamp oak we are using, we have had a marked degree of success in using vapor drying for the reduction of splitting and checking in the seasoning period. With that in mind, we have been able to accept other species that we wouldn't have cared to accept or try to handle through the seasoning period without the ability to handle them by vapor drying, thus preventing a great degree of fall-down and loss during that seasoning period.

I would like to direct the next question to Mr. Drew.

Mr. Drew, what use can be made of cross ties not meeting first—quality specifications?

Mr. Drew: This is a rather controversial question, but for those railroads where first-quality ties are difficult to obtain, and they are forced to take second-quality—or, rather, ties that do not meet first-quality specifications—they cannot afford to just cast them aside. They must be used.

These can be used in sidings, unimportant branch lines, back tracks, industry spurs and, as previously stated, in tracks which possibly will be abandoned before too many years.

There are other uses which we have found of considerable advantage in the poorer qualities. They can be used for cribbing, for sills on unimportant buildings, for the blocking of loads in cars, where we have a considerable problem, particularly with heavy machinery and structural steel in open-top cars. A shifting load is a rather expensive hazard, and we have found that these low-quality ties are very suitable for that service;

they are used up in one trip and that's the end of them. Otherwise, we have to go into the market and buy rather expensive lumber.

Chairman Collister: Mr. Brentlinger, should specifications be relaxed informally, when necessary, to achieve sufficient production?

Mr. Brentlinger: Mr. Moderator, we could probably use our entire time on this question, but the panel-type answer is "no." [Laughter]

Chairman Collister? Mr. Drew, may I throw another question your way? Is it economical for a railroad to use mixed hardwoods which they know will have an expected life less than that of various other species of ties?

Mr. Drew: This is another controversial question, and is dependent upon the location of each individual railroad.

If the railroad is fortunate enough to have suitable species of whatever type of wood it chooses to use, there is no problem. Otherwise, it may be forced to use mixed hardwoods of less desirable species in order to take advantage of what is known as the "woods run" in the timber stands adjacent to its line. This is an advantageous approach, because it holds down the price of the tie to the user without increasing the cost to the producer to any extent. Therefore, it's good business.

We have the same thing on a national scale. We are utilizing our natural resources to their fullest extent by using these so-called mixed hardwoods of less desirable species. I, for one, feel that this should be done. However, we must not overlook the statement just made by my associate, Mr. Duncan, that in using these mixed species, they should be separated if at all possible, because no two species will handle exactly the same, either in seasoning or in treatment.

Chairman Colllister: Thank you, Mr. Drew.

Mr. President, we could go on and on, but I think we have already encroached on somebody else's time, and unless there are questions from the floor, this will complete our discussion.

President O'Rourke: Thank you, Mr. Collister.

Surely, on a subject of this importance, there should be some discussion from the floor. Certainly, everyone does not agree with everything that has been said.

J. D. Hudson (Virginian): I'd like just a little more discussion on the incising of ties.

Chairman Collister: Mr. Kistler, would you like to add something on this?

Mr. Kistler: That question, like the one that Mr. Brentlinger just had, could be discussed here all morning and all afternoon. We might clarify it a little if the gentleman would mention just what particular phase he means.

Do you mean the incising of oak, or do you mean the incising of all ties, or do you mean incising of fir, incising of miscellaneous hardwoods, or ties of other species of wood? In other words, if you could be a little more specific, perhaps it would help me.

Mr. Hudson: We are more interested in mixed hardwood than anything else.

Mr. Kistler: By mixing hardwood, do you mean beech, birch and maple in the North, or southern mixed hardwoods? [Laughter]

Mr. Hudson: Mixed oaks.

Mr. Kistler: I didn't mean to be impertinent, but it is necessary to clarify the question. Generally speaking, I think most of us cannot think of the mixed oaks as being mixed hardwoods. In the North, when one speaks of mixed hardwoods, he usually means beech, birch and maple, whereas, in the South he means an entirely different species of timber.

Again, I think the question of incising the oaks is more or less an individual question. In some hill oaks, in my opinion—and I am thinking particularly of red oak—there are no benefits whatsoever to incising. On some southern oaks, and swamp oaks, with incising, the greatest benefits are from the eliminating of severe checking and splitting. In other words, you have more fine checks. Also, it does assist somewhat in penetration of the preservative.

That's about as near a definite answer as I believe I can give you.

MR. BURT: Mr. Moderator, may I comment on that?

CHAIRMAN COLLISTER: Yes, Mr. Burt.

MR. BURT: I have full appreciation that the question asked is probably one of the most important that we have before the industry today. It may be that, before too long, we will all come to the incising of mixed hardwoods of all species, and probably oak, but as of just now, I do not believe that we have had quite enough experience to determine the full economic worth of incising.

Of course, present indications are that incising mixed hardwood does a lot of good with respect to reducing checking and splitting of ties during the seasoning period, but I doubt very much if we know enough now about what happens to those same ties after they are placed in track. I firmly believe that holds true with regard to oak.

CHAIRMAN COLLISTER: Mr. Duncan, would you care to elaborate a little further?

MR. DUNCAN: About 25 years ago, I was appointed chairman of a committee to investigate the incising of hardwood ties. I was at Delson, up near Montreal, Canada, where there were two large stocks of railroad ties, owned by the two large Canadian roads. One railroad incised its ties green, when received, and the other did not.

Well, I had probably thirty fellows out looking at those ties. We spent most all day at the job, and then we tried to formulate a report. The opinion was about equally divided.

Those ties were the northern hardwoods—beech, birch and maple, and also oak. I was interested in it, so I undertook a test of white oak and red oak ties, incised and not incised. The ties were all hill oak. I don't remember the exact number; there were possibly 250 in the test. Half of them were incised green; after they were all seasoned, they were all treated at the same time and all put in track. An equal amount of white oak and red oak were incised, seasoned and treated.

As I remember, those ties were put in track in 1935. We watched them very carefully, year after year. I couldn't see much difference developing in them, so I let them alone until late last fall. I had all the ballast removed so we could examine the ties carefully. Without looking at the numbers and checking the record, it was impossible for me to tell, by looking at the ties, which had been incised and which had not. Practically none of the ties had been removed. Some had been damaged by burning, where engines had cleaned their fires.

CHAIRMAN COLLISTER: Thank you, Mr. Duncan.

Any further questions?

PRESIDENT O'ROURKE: Surely, someone has had some experiences to add to this discussion, or perhaps can ask a question of this panel.

H. B. Christianson, Sr., (Milwaukee Road): What determines when an air-cured tie is ready for treatment? What is the yardstick?

CHAIRMAN COLLISTER: Mr. Brentlinger, would you like to answer that question?

MR. BRENTLINGER: The controlling factor, of course, is moisture content. The figures and data show that, as a general rule, between 45 and 50 percent in hardwood ties is about the lowest moisture content we can get.

Of course, it isn't practical to run moisture contents all the time, through the oven. It is done visually, with extraction cores that indicate the extent of dryness from the outside surface, and exterior evidence like checking and drying.

Your moisture content is most important, because the water must be out of the tie before we can get the oil in there. It must not only be out of the tie, but the tie must be prevented from losing water in the track.When the tie loses moisture in the track, it checks, and untreated wood is exposed, and that's when decay begins.

PRESIDENT O'ROURKE: Are there any other questions, discussion, or comment?

G. M. Magee (AAR): I'd like to know what yardstick you would use in determining when a tie should be removed from track, a tie that is otherwise sound except for tie plate cutting.

CHAIRMAN COLLISTER: That's a really good question. [Laughter]

MR. BRENTLINGER: I don't believe that we people in the tie inspection business—as it is generally thought of—can answer that question. Perhaps some of the railroads that have tie inspectors who specialize in tie removals might answer it, but it seems to me that it should go back to the audience, because some of the track people are probably in much better position to tell us than we are who passes on the green quality of the tie for the good tie you want.

MR. BURT: The moderator, himself, is one who might answer that one.

CHAIRMAN COLLISTER: I was hedging a bit. From our study of the causes of removal of ties, which has been rather extensive—our inspectors have seen about 450,000 ties in the last six years, individually and personally making inspections, both before and after the tie has been taken out of the track—we have found (varying with the species of wood and the conditions of track) that about 3 percent of our ties are being removed after 24 years' service life for decay, 25 percent for plate cut, and about 65 percent for split, shatter and other large checks. A very small percentage of them are coming out because of spike kill, and a small percentage because of damage because of derailment and accident damage.

PRESIDENT O'ROURKE: I was looking at the expression on your face, Mr. Magee. Were you answered to your entire satisfaction? [Laughter]

Is there anyone in the audience who can answer his question? It was suggested by one of the panel members that perhaps someone in the audience could satisfactorily answer Mr. Magee.

CHAIRMAN COLLISTER: One thing further, Mr. President.

The Tie committee met at Orrville, Ohio, about 2 years ago and examined some 50-odd ties that had been removed from track by the Pennsylvania Railroad, and that was the most interesting part of our morning meeting. I think there were 25 people there, and each tie had 25 different reasons for being taken out of track. [Laughter]

PRESIDENT O'ROURKE: Is there any further discussion?

If not, I want to thank you again Mr. Collister, and your committee, for your interesting presentation. We particularly appreciate the contributions made by the members of your discussion panel on the importance of adhering to specifications, the possibility for greater use of timber stands, and anti-splitting devices and methods.

The committee is now excused with the thanks of the Association. [Applause]

The next committee to report is our Committee 5—Track, of which Mr. L. L. Adams, chief engineer, Louisville & Nashville Railroad, is chairman. May I ask that Chairman Adams and the vice chairman and secretary of the committee join me at the

main speakers' table, immediately to my left, and that all reporting subcommittee chairmen, or others to make presentations, take places to my right and left at the main speakers' table, as near the podium as possible.

Mr. Adams, the floor is yours for your presentation.

Discussion on Track

[For report, see pp. 683–774.]

[President G. M. O'Rourke presiding.]

Chairman L. L. Adams (Louisville & Nashville): Mr. President, members and guests: It is with regret that your committee reports the death during the year of two of our members, Mr. J. W. Hopkins, engineer of track, Bessemer & Lake Erie Railroad, on April 5, 1955 (a memoir for Mr. Hopkins appears on page 684 of our report in Bulletin 528), and Mr. Harold S. Ashley, engineer maintenance of way, Boston & Maine Railroad, on February 12, 1956. A memoir will be prepared for Mr. Ashley.

Your committee had 10 assignments, and all subcommittees have progressed their work throughout the year. Our report is published in Bulletin 528, pages 683 to 774, incl.

Assignment 1—Revision of Manual. There is no report on Assignment 1, as recommended revisions to the Manual are included in reports on our Assignments 2, 3 and 9.

The report on our Assignment 2 will be presented by Subcommittee Chairman C. E. Peterson, assistant engineer of the Santa Fe.

Assignment 2—Track Tools, Collaborating with Committees 1 and 22, and with Purchases and Stores Division, AAR, was presented by Subcommittee Chairman C. E. Peterson (Santa Fe).

[Mr. Peterson, reading from the printed report on this assignment, presented the Manual recommendations of the committee in a series of three motions, all of which were regularly seconded, put to a vote, and carried. He then presented verbatim Part 2 of the report, as information.]

Chairman Adams: The report on Assignment 3 will also be made by Mr. Peterson, due to the fact that Subcommittee Chairman M. J. Zeeman, engineer of track design of the Santa Fe, was unable to be here.

Assignment 3—Plans for Switches, Frogs, Crossings, Spring and Slip Switches, Collaborating with Signal Section, AAR, was presented by C. E. Peterson (Santa Fe) in the absence of Subcommittee Chairman M. J. Zeeman (Santa Fe).

[Mr. Peterson read in full that part of the printed report on this assignment affecting the trackwork plans and moved that the recommendations of the committee be adopted. The motion was regularly seconded, was put to a vote, and carried. Mr. Peterson then read that part of the committee's report introducing Appendix 3–a and 3–b.]

Chairman Adams: The report on Assignment 4 of our committee will be made by W. E. Cornell, engineer of track of the New York, Chicago & St. Louis Railroad.

Assignment 4—Prevention of Damage Resulting from Brine Drippings on Track and Structures, Collaborating with Committee 15 and Mechanical Division, AAR, was presented by Subcommittee Chairman W. E. Cornell (Nickel Plate).

Mr. Cornell: Mr. President and gentlemen: On this assignment, Mr. Magee and Mr. Coburn of the AAR research staff are continuing their tests at the laboratory to

develop other suitable chemicals in comparison with at least one already found, that is, sodium polyphos. That has met most of the requirements for a suitable inhibitor; it is non-toxic, and also does a pretty good job.

Probably more interesting to you is the fact that the Canadian National Railroad has, for the past three years, been using sodium polyphos in its refrigerator cars, and as of now some results should be forthcoming. I understand from Mr. Magee that he is going to Canada this summer to study the results on the Canadian National, following which I think he will probably have something very interesting to report.

Chairman Adams: The report on our Assignment 5 will be made by Subcommittee Chairman V. C. Hanna, chief engineer of the Terminal Railroad Association of St. Louis.

Assignment 5—Design of Tie Plates, Collaborating with Committees 3 and 4, was presented by Subcommittee Chairman V. C. Hanna (TRRA of StL).

Mr. Hanna: Mr. President and members: The committee presents a progress report on Assignment 5, submitted as information, covering 1955 field service tests of 7 designs of tie plates for a rail base width of 6-in on the Cincinnati, New Orleans & Texas Pacific Railway, and a description of the reinstallation of special 8 by 15 by 1-in tie plates on the Illinois Central single-track line near Dubuque, Ia. Complete details of both projects, including charts and tabulations, are set forth in Bulletin 528.

In November 1944, 7 designs of tie plates were installed in 22 panels of single-track main line laid with new creosoted ties, stone ballast and 131 RE rail in Mile 326 near Chattanooga, Tenn. Eight of these test panels are located in a short 6-deg curve having 6-in elevation and oak ties, and 14 panels are located on tangent track and equally divided as between oak and pine ties. The service tests are designed to develop information on plate cutting, possible permanent bending of the plates and gage widening.

During the last service period, extending from June 1953 to April 1955, the gross tons of traffic increased from 187 to 228 million gross tons, but there has been no acceleration in the rate of plate cutting on the test curve or tangent. Using average values of tie abrasion for the 4 panels with 14-in tie plates, the plate cutting on the outer rail was 25 percent greater than on the inner rail, and was 43 percent greater on oak ties on the curve than on oak ties on tangent track. On tangent track the soft wood ties were plate cut 34 percent deeper than the oak ties These tests, as well as others, have shown that cut anchor spikes did not effect a reduction in plate cutting.

Tie plate penetration has not increased sufficiently to show the benefit of the larger plates, none of the tie plates have become permanently bent, and a longer service period on the CNO&TP test will be required to develop the advantage of the longer tie plates and to determine if the thinnest plate (for its length) will become permanently bent.

The gage of the 6-deg curve has changed little since rail relay in December 1952. An analysis of gage widening on the curve during the entire service period indicates that the part attributed to horizontal plate movement was smaller with ribbed-bottom plates than with the flat bottom design, and previous reports on this test have shown that the ribbed-bottom plates held gage as well as the flat bottom type with at least one less cut spike.

As stated in the last report of the committee, the service test of the special 8 by 15 by 1-in tie plates with 1¼-in eccentricity under the inner rail of a 4-deg curve on the Illinois Central near Curve, Tenn., was terminated. These plates are similar to AREA Plan No. 20, except that they were made of 1-in uniform thickness plates with a milled rail seat and bars welded in place for shoulders.

These plates were reinstalled on a 6-deg curve on a long hill ascending westward on an 0.85 percent grade, located at Mile Post W–188 on the single-track line west

of Dubuque, Ia., on the Illinois Central Railroad. The curve has 4½-in elevation and is restricted to 40 mph for passenger trains and 35 mph for freight trains, with annual traffic of approximately 16 million gross tons.

The installation was made in the first half of August 1955, consisting of 4 test sections of 2 track panels each, with twenty-four 7 by 9-in by 8-ft 6-in sawed creosoted oak ties per panel. Three of the sections have the special 15-in plates on the inner rail and 13-in AREA Plan No. 7 plates on the outer rail. Racor studs, tie plate lock spikes, and cut spikes are each used as hold-down fastenings (2 per plate) in both rails of 2 panels of track. The fourth section, for controls, has 13-in tie plates under both rails and cut spike construction.

Field measurements will consist of tie abrasion, gage of track, elevation and curvature of each panel of track. These measurements, except for tie abrasion, will be extended to include two panels of the Illinois Central construction, with new ties, at each end of the stretch.

The Association gratefully acknowledges the splendid cooperation and assistance rendered by the Southern Railway and the Illinois Central, and is indebted to the suppliers for their valuable assistance.

President O'Rourke: Thank you, Mr. Hanna.

Chairman Adams: Our report on Assignment 6—Hold-Down Fastenings for Tie Plates, Including Pads Under Plates, Their Effect on Tie Wear, will be made by the chairman, Mr. J. S. Parsons, assistant chief engineer maintenance of way of the Erie.

Assignment 6—Hold-Down Fastenings for Tie Plates, Including Pads Under Plates, Their Effect on Tie Wear, Collaborating with Committee 3, was presented by Subcommittee Chairman J. S. Parsons (Erie).

Mr. Parsons: Our report covering tests being run on the Louisville & Nashville Railroad and the Illinois Central Railroad this year covers at some length and detail current findings on the effectiveness of holddown fastenings for tie plates, tie pads under plates, and their effect on tie wear.

These tests, begun in 1947, are for the primary purpose of developing information for determining the most effective and economical methods for increasing the service life of ties by minimizing plate cutting and reducing the frequency of regaging and readzing curves through the use of special hold-down fastenings, tie pads, etc.

During 1955, four short test sections with new creosoted oak ties, 14 in flat bottom tie plates, and two each of cut linc and anchor spikes were installed in a 5-deg curve in the vicinity of East Bernstadt, Ky., on the L&N during June. One section consists of 13 ties with 8 by 14-in Nox-Rust tie seals placed on the adzed surfaces. These seals are premoulded sheets of asphaltic material approximately ⅛ in thick. This material is similar to Protek-Tie which was applied in the L&N test section in 1953, except that it is modified to be a solid instead of a liquid, for rapid use in connection with relay rail work.

A second section has 36 ties with 8 by 14-in natural rubber pads ¼ in thick and uncoated, furnished by the Railroad Products, Inc.

The third new test section installed on 35 ties is a Johns–Manville formulation of ¼ in thick fiber rubber tie pads which are bottom coated.

The fourth 1955 installation is a recently developed Fabco pad having an improved coating on the bottom and a seal coat on the top to keep them from sticking together in transit. These pads were placed on 36 ties, and for retention of the coating on the bottom the pad surface was abraded.

These new tests, as well as those started in 1947 and those added to at various times, are being conducted and closely followed by the AAR research staff under the general direction of G. M. Magee, director of engineering research, AAR, and H. E. Durham, research engineer track and his staff. The report as submitted in this year's Bulletin is for information only.

The tests have reached the stage, as you will find from analyzing the findings to date, where it can be stated that a durable and well sealed tie pad and a good hold-down fastening are of sound economic value when applied on curves and when used in connection with the installation of bridge timber. The economic value, of course, must be weighed from the standpoint of initial cost of the tie or timber and the cost of the tie pad or hold-down fastening. We are convinced, however, that the tie pad is economically sound for use on bridge deck installations, as well as on the low side of heavy curvature, provided that the pad applied has a good bond with the tie, and that no serious delamination, stretching, mashing out, etc., results after several years' service.

We have found, based on service tests, that the following pads have shown the better performances:

1. Bird original fiber rubber.
2. Bird improved fiber rubber.
3. Fabco.
4. Bird five or seven-ply duck burlap.
5. Burkhart fiber.
6. Dunne's moulded rubber.
7. Racor fiber rubber.
8. Bird vinyl pads.

Hold-down fastenings are proving of value on curves, and while your committee is not presently in a position to recommend which of the tested hold-downs are the most economical, it can be said that the Bernuth, Lembcke hold-downs and the Racor studs are giving the best results to date from the standpoint of holding down costs and maintenance.

The cut spike, however, is doing a good job and cannot be discredited for effect and value.

It is hoped that within the next year or two results will indicate sufficient information so that more definite recommendations can be made as to what extent both tie pads and hold-down fastenings should be used.

President O'Rourke: Mr. Adams, may I say to the convention that this subject should certainly bring forth some discussion from the floor. This matter of the use of tie pads and hold-down fastenings is certainly a live one, and a matter of great discussion in the field, and I would think that somebody here would have some question or comment on the work of this subcommittee and its findings.

Mr. Adams, I would like to ask a question. Mr. Parsons mentioned cross ties in track, and bridge ties. How about pads under railroad crossings? Have you done anything about that in the way of study?

Chairman Adams: We have decided it would be economical to use pads under crossings, together with good hold-down fastenings. At crossings, the ties should be protected more than anywhere else, due to the cost of installation.

Does that answer your question?

President O'Rourke: Partially. I am ready to admit that the use of pads will probably prolong the life of the timber, but how about the crossing itself? Is the period

of time between grindings extended, is the building up of the crossing less expensive, or is the frequency less because of the use of the pads?

Chairman Adams: Mr. President, I misinterpreted your question. When you said "crossings," I was thinking of highway grade crossings.

There is no doubt but that pads under railroad crossings will preserve the life of the crossing, and will extend the time between grinding and other maintenance of the crossing itself. They cushion the blow of the wheels over the crossing, and we think it is economical to use them.

Now, that is my opinion. I wouldn't say that is the opinion of the entire committee. Some of the committee members might disagree with me on that.

President O'Rourke: Is there some other view on this matter?

G. M. Magee (AAR): I think several individual railways have conducted tests on the use of pads under the crossing frogs, but it was not until this year that the track committee had us include a study and tests of pads under crossings in our research budget. That is under another subcommittee of the Track committee, and we are setting it up this year. We are trying to make arrangements on what we call our frog proving ground at McCook, Ill., to get some pads put in and to get some stress measurements on the points, to see to what extent the pads may be helpful in reducing the structural stresses in the crossing frogs. We also hope to get some indications of the effect of the pads in reducing the impact load that is applied to the crossing itself, and the frog itself, and to the supporting ties.

As I have said, this work is just being started this year, and so, from the standpoint of the work that we are doing for the track committee, we have nothing to report now. However, I hope we will have something definite within the next few years on this subject.

President O'Rourke: Thank you, Mr. Magee.

J. L. Gressitt (Retired, Pennsylvania): It is a matter of record on the Pennsylvania that several years ago crossing frogs were equipped with a complete set of pads, because it was felt there would be a benefit from such an installation. However, the results were not favorable in that test, with reference to the costs and the early failure of the pads. Perhaps now, that there are better pads available, better results can be obtained.

President O'Rourke: Any other discussion? If not, please proceed, Mr. Adams.

Chairman Adams: The following two assignments appear to meet head-on, due to the opposite results that they attempted to obtain. The first of these is Assignment 7—Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings, and will be presented by Subcommittee Chairman R. G. Garland, assistant engineer of the Santa Fe.

Assignment 7—Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings, was presented by Subcommittee Chairman R. G. Garland (Santa Fe).

Mr. Garland: Mr. President, gentlemen: The study of the effect of lubrication in preventing frozen rail joints and retarding corrosion of rail and fastenings is progressing.

Tests on the Illinois Central are now five years old and the committee has found that there is a definite reduction in corrosion of rail and joint bars where the rust preventives have been used. Since most of the five year old test sections had brush coats only, some of the sections will be terminated so that a concerted effort can be made in the investigation to determine the most economical and effective methods for preserving old rail joints.

In connection with the study of spraying rail joints annually, we have expanded the spray method test sections by starting tests using three new materials. These new test sections were set up on 131-lb rail laid in 1944, using 6-hole, headfree joint bars.

We plan to continue the spray method of lubrication of rail joints and make an economic analysis of the various methods of rail end lubrication.

In the portion of our report to the Association that deals with the laboratory brine corrosion tests of the various metal preservatives, we say that the Armite Compound No. 500, furnished by Armite Laboratories, costs about 60 cents a pound. Since the report was published, we have been advised by the Armite people that they are now in a position to furnish this compound at 22 to 24 cents a pound, depending upon the quantity of the purchase.

CHAIRMAN ADAMS: Our report on Assignment 8—Laying Rail Tight with Frozen Joints, will be presented by J. B. Wilson, Atlanta & West Point, and Georgia Railroads.

Assignment 8—Laying Rail Tight with Frozen Joints, was presented by Subcommittee Chairman J. B. Wilson (Atlanta & West Point).

MR. WILSON: Mr. President and members: The assignment "Laying Rail Tight With Frozen Joints" is a new one. It was given the committee because some of the member roads, with a relatively large proportion of main track mileage with medium and sharp curvature, did not believe it wise to lay continuous welded rail because of the complications in transposing rails on the curves and the inconvenience and cost of relaying welded rail on secondary tracks.

The objective of the committee is to conduct a service test on rail laid tight with high bolt tension and compare it with rail laid with normal expansion and bolt tension. The things that will be investigated are: (1) rail end batter, labor tamping up the joints and building up or grinding the joints; (2) pull-in or total joint wear of the joints; (3) the frequency of retightening of the bolts in tight vs. normal joints; and (4) other costs, such as lining track at the joints, maintaining rail anchors, bolts and signal bonds, and the respacing of ties.

Mr. L. L. Adams, chief engineer of the L&N, and chairman of our committee offered to let us make the test on his road, explaining that he had laid a section of tight rail about ⅞ mile in length south of Nashville, Tenn., in the fall of 1953, and that he planned laying a similar section of tight rail in 1955 that we could use for our study. When members of the committee and the AAR research staff met on the ground to look over the proposed section of track to be laid tight, and to observe the section that had already been laid, we decided that to save time and to advance the investigation more rapidly, we would use the section already laid as the test section. Our reasons for this decision was that the joints were closed and most of them were in good condition with little or no chipping, although the rail was 22 months old and had carried approximately 22 million gross tons of traffic, and that the adjoining track which had been laid at the same time according to normal practice could be used for the comparison test track.

In October 1955, the AAR research staff numbered and loosened the joints, retightened bolts in the tight section to between 40,000 and 45,000-lb tension and on the normal joints to between 15,000 and 25,000 lb tension, using a bolt tension extensometer. They also took initial or base reading on 20 joints (10 in each rail) in each section as follows: rail surface profile, and out-to-out readings on the joints for determining the pull-in or joint wear. All rail joint gaps were measured and steel bars were set to measure cumulated rail creepage at one-quarter points in the tight rail section and at one-third points in the normal rail.

It is our plan to check rail gaps and creepage each summer and winter. From the data obtained, the frequency of retightening of bolts in the tight section will be determined. In the normal rail, bolts will be retightened each autumn.

Next year we will be able to give you a definite report on our first year's measurements.

PRESIDENT O'ROURKE: Thank you, Mr. Wilson.

Is there any discussion on this report?

Mr. Adams, has your committee—or have you—given any thought to trying this kind of test on track other than that subjected to brine drippings—corrosion? I'm thinking of suburban system tracks, such as in the electrified territory of the Illinois Central, or maybe other railroads, like the North Western or the Milwaukee, where they have diesel power but no freight trains.

CHAIRMAN ADAMS: The section where we laid this rail with frozen joints was not particularly subjected to brine drippings.

It is true that where you have damage from brine drippings, I think the frozen joint construction would have an advantage over the welded rail because of the shorter time that would be required to renew it. We are experimenting with frozen joints because we have so many curves, and we feel that we can get this type joint developed to the point where it will be more economical than welding the rail.

PRESIDENT O'ROURKE: Is there any other discussion on this report?

Proceed, Mr. Adams.

CHAIRMAN ADAMS: Our next report is on Assignment 9—Critical Review of the Subject of Speed on Curves as Affected by Present-Day Equipment, Collaborating with the AAR Joint Committee on Relation Between Track and Equipment. The report on this assignment will be presented by Mr. W. R. Bjorklund, district engineer of the Northern Pacific Railway.

Assignment 9—Critical Review of the Subject of Speed on Curves as Affected by Present-Day Equipment, Collaborating with the AAR Joint Committee on Relation Between Track and Equipment, was presented by Subcommittee Chairman W. R. Bjorklund (Northern Pacific).

MR. BJORKLUND: The assignment relating to speed on curves and through turnouts has developed that modern passenger equipment can negotiate curves at higher speeds than older equipment because of the improvement of roll stabilizers, swing hangers, and large center bearings.

The current data in the Manual states that passenger equipment will ride comfortably around curves at speeds which would require an elevation 3 in higher for equilibrium. Actually, this means that 3-in unbalanced elevation in the track, plus the unbalanced elevation due to car body roll, will give a comfortable ride. If the car body roll can be decreased, then the unbalanced elevation in the track can be increased as the total unbalanced elevation due to track and car body roll is a constant.

When superelevation is placed in the track with a track level, the bearing distance of the track level on the rail is the equivalent of center to center of the two rails which, in turn, is also the center of bearing of the load on the rail. Therefore, the table of equilibrium elevation is based on center to center of rail instead of the previously used gage of track, or 4 ft 8½ in.

Railroads which desire to operate trains at greater than 3-in unbalanced elevation should make lean tests to determine the roll angle of cars, and thereby ascertain the amount of unbalanced elevation on which those particular cars can operate with comfort to passengers.

The present Manual information covering speed through turnouts has been completed to show speeds for all turnouts now in common use, including both lateral and equilateral turnouts with straight and curved switch points.

Mr. President, I move the adoption of the revisions presented on pages 764–767 of Bulletin 528 and their inclusion in the Manual.

[The motion was regularly seconded, was put to a vote, and carried.]

CHAIRMAN ADAMS: Thank you, Mr. Bjorklund.

Our report on Assignment 10—Methods of Heat Treatment, Including Flame Hardening of Bolted Rail Frogs and Split Switches, Together with Methods of Repair by Welding, will be presented by Mr. S. H. Poore, assistant engineer on Chesapeake & Ohio Railway.

Assignment 10—Methods of Heat Treatment, Including Flame Hardening, of Bolted Rail Frogs and Split Switches, Together with Methods of Repair by Welding, was presented by Subcommittee Chairman S. H. Poore (Chesapeake & Ohio).

MR. POORE: Mr. President and gentlemen: This is simply a progress report. However, it may be of interest to review the assignment briefly.

Your committee, with the help of the frog and switch producers and welding companies, working with the AAR research staff, has brought about the installation of 24 simulated crossing panels on the Chicago, Milwaukee, St. Paul & Pacific Railroad at Mannheim, Ill. These crossing panels contain sections of heat-treated and flame-hardened construction, treated by various producers, together with panels of non-heat-treated, control-cooled rail and chrome-vanadium rail. This installation has been in track now for about two years.

Some welds have been made on test samples held out for the purpose. The data obtained from these welds have not been fully analyzed at this time. However, they are reported on briefly in our report.

The present report includes certain figures as to the Brinnell hardness of the test panels, together with wear and batter readings which may be of interest to you in this connection.

The report is presented as information, and the committee hopes to continue its work to bring forth some usable conclusions very soon.

CHAIRMAN ADAMS: As a special feature of our committee presentation, I desire to present at this time Mr. C. J. Geyer, retired vice president—Construction and Maintenance of the C&O Railway, who is well known to all of you. Mr. Geyer is a past president of the American Railway Engineering Association, and was a member of the Track committee for a number of years, serving three years as its chairman. He will review for you the past work of the Committee.

Highlights of Work Performed by Committee 5—Track

By C. J. Geyer

Retired Vice President, Construction and Maintenance, Chesapeake & Ohio Railway

It was a pleasure to accept the invitation of the Track committee, through its chairman, Mr. Adams, briefly to summarize the work of the Track committee through the past years.

To me, the Track committee is one of the most important committees of the Association. My first assignment with AREA was on this committee.

Good track for dependable train operation is, in my opinion, a major factor in the success of a railroad. The founders of our Association also thought track a very important subject, because Committee 5—Track was one of the original 14 committees and reported at the first convention of this Association 56 years ago.

There were 10 members of the first Track committee, including E. A. Handy, chief engineer, Lake Shore & Michigan Southern Railway, as chairman.

The present committee has 65 members and associate members, with L. L. Adams, chief engineer, Louisville & Nashville Railroad, as chairman. There are 57 members who are supervisory and executive officers from the railroads, and 8 associate members who are supervisory and executive officers from the manufacturers of materials coming under subjects assigned to the Track committee. The associate members do not have a vote.

This combination of user and maker has proved to be a happy one and results in efficiency and economy for all concerned.

I do not believe there are any of the original Track committee members on the present committee, although some of these "gray heads and bald heads" have been around for a long time.

It is not practical, now, to tell you about all 11 current assignments or the subjects coming under Chapter 5 in 6 parts of our current Manual. I will comment on a few of these assignments and reports; however, I do not mean to imply that they are the most important subjects handled by this committee.

The Portfolio of Trackwork Plans is the assignment that requires the greatest amount of committee time, and time of individual committee members outside of committee meetings. The committee reported first on this subject in 1912 and in every subsequent year. It will continue to be an active subject as long as this Association studies railroad problems. The development of the art requires constant revision and improvement. This assignment includes plans and specifications of switches, frogs, crossings, guard rails and spring and slip switches, in fact, every item of special trackwork.

The Portfolio of Trackwork Plans includes 123 plans in complete detail, with specifications to cover. It involves an enormous amount of work by committee members and representatives of the Manganese Track Society. Here the maker and user work together, resulting in plans of trackwork that is practical to make and economical to use. No other body of men could be brought together to do this job as proficiently.

These plans and specifications are so complete that it is unnecessary for any railroad to spend one penny for technicians, designers and draftsmen to prepare plans and specifications for these items.

It is as easy to order special trackwork from the Portfolio of Trackwork Plans as it is to order an item from a Sears Roebuck catalogue while occupying the "throne in the Chic Sale" room of your home.

Another assignment very similar in personnel of committee and study procedure to special trackwork is that covering track tools. This subject has been studied for many years and, like special trackwork, will never be completed. On this assignment the committee has completed and received approval of the Association on 31 plans for various track tools and the specifications therefor. These plans and specifications are published in the current Manual. For these tools—as for special trackwork—it is unnecessary for a railroad to spend money preparing plans, as the tools can be ordered from Manual reference just as easily as can special trackwork.

One of the outstanding jobs of the Track committee is the preparation of plans and specifications for tie plates to fit all the various rail sections in use in this country. I was a member of the Track committee at the time this particular assignment was

started, and I recall the meticulous care exercised by the committee in order to have plans for tie plates that would result in the lowest annual cost for the rail, tie and tie plate assembly. The late Dr. Talbot worked with the committee and contributed valuable advice in the committee's effort to get a design of plate proper for the rail it holds and the tie it rests upon. Here again it is simple to order the proper tie plates for your rail section right from the AREA Manual.

I will refer only briefly to the "Specifications for Laying New Track" and the "Specifications for Laying Rail". These specifications were prepared with great care by members of the committee who are experts in this field. I suggest that railroad officers directly concerned with track review these specifications from time to time. I am sure the reading will help your work. It is quite possible you may have learned something through your experiences that would improve the specifications if you would give the committee chairman the benefit of your views.

I would like to refer to several of the other subjects handled by the committee and appearing in the Manual, but time will not permit. I will, however, comment on one other committee assignment for the reasons that brought it up for restudy and the object lesson to be learned by this and other committees of this Association.

I refer to "Elevations and Speeds for Curves" appearing in the current Manual and to the present Track committee Assignment 9—Critical Review of the Subject of Speed on Curves as Affected by Present Day Equipment, Collaborating with AAR Joint Committee on Relation between Track and Equipment.

The subject "Elevations and Speed on Curves" was an active study of the Committee in almost every year, 1902 to 1915, incl.

The subject was dropped in 1915, after the Committee had submitted its report which was accepted by the Association as recommended practice and publication in the Manual. This report included a graph showing overturning speeds for certain curves with given elevation, and reference to the 3-in unbalanced elevation, but no information as to practical application.

In those early years, the committee and the other Association members were evidently of the opinion that committee action was for the interpretation and use of Association members only, and that it was of no concern to public bodies and others. The Manual material and progress reports leading up to its approval were ample for practical application by railroad supervisory officers. However, the Association grew rapidly beyond the provincial stage and is now the recognized authority on matters pertaining to the construction and maintenance of fixed railroad property.

The Manual material on "speed" as of 1915 remained without change until 1929. About the middle 'twenties there was a passenger train derailed on a curve. The cause of derailment was not determined. A personal injury claim reached a jury trial. The plaintiff's attorney made the point that the speed of the train was not in accordance with recommended practice as published in the AREA Manual, and that this was the cause of the derailment. The speed of the train was well within safe limits and in accordance with the practical application of recommended practices, but this was not clear to a layman jury.

To clear up such a misapplication, the subject was reassigned, and in 1929 the committee recommended additional tables showing equilibrium, comfortable, safe and overturning speeds for trains on various curves with given elevations. In addition to the tables and formulas, there were notes showing the practical applications and the necessity and safety in operating trains at different speeds around a given curve with fixed eleva-

tion. In subsequent years this material has been revised for clarity from time to time, but the practical explanation for its use has been retained.

I have discussed this subject at some length in order to highlight the pitfalls that must be avoided by all of our committees in making their reports, and particularly in regard to material for the Manual. The railroads today are paying heavily by being forced to follow practices recommended by technical societies because of misinterpretation as to practical application.

I will take this opportunity to urge every railroad executive officer to follow AREA Recommended Practices on his railroad and thereby makes a substantial saving for his property, or to have on record with the secretary of this Association his reasons for not accepting them. His reasons could possibly save the other railroads millions of dollars.

I feel sure that if you follow the Recommended Practices of the Track committee, your railroad will not be the object of the little jingle written by a passenger which goes—

"The way these cars roll in and out,
There raises in my mind a doubt
As to whether the man that built the track
Was agoin' to hell or acomin' back."

[Laughter and applause]

CHAIRMAN ADAMS: Thank you, Mr. Geyer, for an interesting review of the past work of Committee 5. I feel sure that this work will be carried on successfully in the future.

Mr. Geyer brought out one point that I was going to mention myself—that so many roads do not follow the plans and specifications as prepared by the Track committee. This committee is made up of engineers representing most of the railroads of the country. I know that some roads whose representatives have been very active on the committee in preparing the plans do not use the plans after they are prepared. When you get a combination of railroad engineers and representatives from the manufacturers working on these plans like the committee does, I don't see how anybody can improve on them to any great extent.

I'd like to hear some discussion as to why these plans are not more generally used, so the manufacturers can stock ahead, knowing that if one road doesn't need an item, another no doubt will. Has anyone any comments on this? I think those who are not using the AREA plans are too guilty to say anything. [Laughter]

Mr. President, this concludes the report of the Track committee, and I want to extend my thanks to the members of the committee for the excellent work they have performed during the year, and also for the excellent support they have given me throughout the entire three years that I have served as chairman.

Especially, I desire to thank our Associate Members of the frog and switch companies who have performed outstanding work in preparing plans under our Assignment 3.

I also desire to thank Secretary Howard, Mr. Magee, and their staffs, for the very valuable assistance which they have given this committee throughout the entire time I have served as chairman.

This ends my term as chairman, and I now turn the chairmanship over to my successor, W. E. Cornell, engineer of track, Nickel Plate Road. Stand up and be recognized, Mr. Cornell. [Applause]

Mr. President, this concludes the report of Committee 5—Track.

PRESIDENT O'ROURKE: Thank you, Mr. Adams, and your committee, for a most interesting report, and thank you, Past President Geyer, for your interesting review of the important work carried out by Committee 5 over the past years.

Mr. Adams, the Association is greatly indebted to you for the able manner in which you have directed the work of our Track committee for the last three years, and I congratulate you upon the important work which has been accomplished under your direction.

We are happy to welcome as the new chairman of Committee 5, Mr. Cornell, and your new vice chairman, Troy West, engineer of track of the Union Railroad. We are sure that the work of your committee will go forward aggressively under their direction.

Your committee is now excused with the thanks of the Association. [Applause]

Our next committee to report will be Committee 1—Roadway and Ballast. The chairman of this committee for the past three years has been Col. B. H. Crosland, chief engineer maintenance of way, St. Louis–San Francisco. I shall be glad if Col. Crosland and the other members of his committee will come to the platform to make their presentation.

Discussion on Roadway and Ballast

[For report, see pp. 643–682.]

[President G. M. O'Rourke presiding.]

CHAIRMAN B. H. CROSLAND (Frisco): Mr. President, fellow members and guests: The very first thing when I got up here, the President suggested that we hurry it up, because the program is falling behind schedule. Seems like I'm always in that spot. Last year they accused me of being a naval commander and hollering, "Gun Number 1—fire! Gun Number 2—fire!" And so on. But, on the presidents' orders, we'll try it again.

PRESIDENT O'ROURKE: Thank you.

CHAIRMAN CROSLAND: Committee 1 is given quite a diversity of subjects for study. We have 10 standing subcommittees, each with its regular chairman—some of them divided into sections. Many of these subcommittees are just getting started on new studies and have not reached a point where they feel they should make a report.

In making our report, we will call on the subcommittees that are reporting, in numerical order, with the exception of Subcommittee 6, which will be held until last, in order that it might introduce a speaker who will discuss a very interesting and instructive subject.

We are very much dependent upon all of the members of the Association to help us study the subjects given to us, and we appreciate your support very much. We would like to have you offer any suggestions, questions or comments from the floor as each one of these subcommittee chairmen reports. At the end of each report, the chairman will pause to give you that opportunity, and we hope you will take advantage of it.

The full report of the committee is found in Bulletin 528, beginning at page 643.

Our first report will be on Assignment 4—Culverts. The report will be given to you by the chairman, G. B. Harris, assistant engineer, Chesapeake & Ohio Railway.

Assignment 4—Culverts, (b) Specifications for High-Pressure Gas Lines, was presented by Subcommittee Chairman G. B. Harris (Chesapeake & Ohio).

MR. HARRIS: Mr. President and gentlemen: In 1954 the Association approved for publication in the Manual, Specifications for Pipe Line Crossings under Railway Tracks, Sec. A. For Flammable Substances. Art. 3 of these specifications, found on page 1–5–1

of the Manual, contains a reference to the current edition of the American Standard Code for Pressure Piping, Number ASA B31.1. At that time the current edition of the ASA Code was the one published in 1951.

Subsequent to the approval of the AREA specifications in 1954, the Sectional Committee on Code for Pressure Piping began revising its Code ASA B31.1. An entirely new Sec. 8 has been written to cover Gas Transmission and Distribution Systems, superseding the old Sec. 2. This Sec. 8 was published during 1955. A new Sec. 9 to cover Oil Transportation Piping, which will supersede the old Sec. 3, is in the process of revision and should be published sometime during 1956.

In the interest of clarification, the committee feels the present reference to ASA B31.1 should be changed from "the current edition" to "the 1951 edition," especially until such time as the ASA completes its new specifications. Committee 1 will then be in a position to review the subject and recommend any necessary changes.

Mr. Chairman, I, therefore, move that Sec. A. For Flammable Substances, of the Specifications for Pipe Line Crossings Under Railway Tracks, found on pages 1–5–1 to 1–5–6, incl., of the Manual, be reapproved with the following revision:

Change the first two lines under Art. 3. Carrier Pipe, page 1–5–1, to read, "Carrier line pipe inside of casing under railway tracks and right-of-way shall conform to the requirements of ASA B31.1–1951, Code for Pressure Piping".

[The motion was regularly seconded, was put to a vote, and carried.]

Last year your committee submitted, as information, a tentative draft of Sec. B. For Non-Flammable Substances, of these same specifications, requesting comments and criticism thereon. Sec. B. For Non-Flammable Substances, with some revisions, mostly of an editorial nature, is now presented with the recommendation that it be approved for publication in the Manual, replacing the present Sec. B.

Mr. Chairman, I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. President, this concludes the report on Assignment 4.

CHAIRMAN CROSLAND: Thank you, Mr. Harris.

Assignment 6—Roadway; Formation and Protection. (The report on this assignment follows the report on Assignment 11).

CHAIRMAN CROSLAND: The report on Assignment 7—Tunnels, will be given to you by the chairman, Mr. J. A. Bunjer, district engineer, Union Pacific Railroad.

Assignment 7—Tunnels: (a) Ventilation; Changes Necessary for Operation of Diesel Power; (b) Clearance; Methods Used to Increase was presented by Subcommittee Chairman J. A. Bunjer (Union Pacific), who read in full the published report of the committee, dealing alone with Assignment (a).

CHAIRMAN CROSLAND: Our next report will be on our Assignment 10—Ballast, and the report will be made by its chairman, R. H. Beeder, assistant chief engineer system, Santa Fe.

Assignment 10—Ballast: (a) Tests; (b) Ballasting Practices; (c) Special Types of Ballast; and (d) Specifications for Sub-Ballast, was presented by Subcommittee Chairman R. H. Beeder (Santa Fe).

MR. BEEDER: Mr. President and gentlemen: Your committee submits as information, report under Assignment 10 (a)—Ballast Tests. This is the third progress report on the oscillator ballast tests now in progress at the AAR Research Center. These tests are

described in detail in the Proceedings, Vol. 54, page 1140, and the Proceedings, Vol. 56, page 717.

Tests have now been completed on a number of ballast materials, including slag, chat, gravel from two sources, several crushed rock ballasts, including trap rock and three limestones from various sources.

Work is being continued on these tests and it is expected that within a year sufficient information will be available to present to you, along with preliminary conclusions.

Chairman Crosland: Our next report is that of Subcommittee 11—Chemical Control of Vegetation. The report will be rendered by the chairman, C. E. Webb, assistant engineer of tests, Southern Railway.

Assignment 11—Chemical Control of Vegetation, Collaborating with Signal Section and Communication Section, AAR, was presented by Subcommittee Chairman C. E. Webb (Southern).

Mr. Webb: Mr. President and gentlemen: The progress report appearing in the Bulletin is in two parts. Part 1 is a review of the research work conducted by the University of Iowa, the University of Montana, and the University of Florida, and, in general, covers results on small-scale test plots with oils and chemical formulations.

Part 2 is a report of the AAR research staff on the performance of weed killers in large-scale applications on various railroads. This also includes a general review of the problems involved in the use of weed killers, and background information on the advantages and disadvantages of the three general types of herbicides.

Earlier work on the control of vegetation demonstrated that the results obtained in one region might not necessarily hold true in other sections. Accordingly, the United States and Canada were divided into seven regions of reasonably comparable vegetation and climatic conditions. The work performed at the universities includes only Montana, Florida and Iowa, but it is contemplated that this will be expanded to other regions.

In Part 2, observations by the AAR staff cover all seven regions, but to date the potentialities of many formulations have not been explored.

At the present time, in its broad aspect, it may be stated that no one compound or combination of compounds meets the requirements of a satisfactory weed killer, and more precise information is needed to utilize the known compounds in the most effective manner.

In spite of the work that remains to be done on this subject, this report and preceding reports may, at this time, provide helpful information for a railroad in selecting a particular weed killer formulation.

The following are general points of interest included in this year's report:

1. The results to date indicate definitely that it is uneconomical to attempt general weed control for more than one season with a single treatment, and that two treatments per season with less expensive chemicals, or lighter rates, may at times be more economical.

2. A clean track is the easiest and cheapest to keep clean. The reestablishment of perennials and reseeding of annuals must be prevented in any satisfactory control program.

3. The resistant perennials appear to be more susceptible to treatment with chemicals, but annuals appear to be controlled more economically by re-spraying with aromatic oils than by attempting to get long-time effects with any chemicals now available.

4. It was noted that some chemicals gave poor results on cinder ballast, whereas the results on soil were excellent, which points out that the type of soil and ballast should also be considered in the selection of a particular formulation.

5. It has also been noted that the effect of two chemicals in combination was sometimes better than either one of the chemicals used separately. This synergistic effect offers many possibilities, and will be investigated further.

6. The arsenites at low rates show promise as contact herbicides that they have not shown on perennials. Available repellents have considerably reduced, but have not eliminated, the livestock hazard.

7. The actual killing properties of oils are not well understood. However, it is believed that the aromatic and olefin content greatly influence their performance. The use of a spectrophotometer has provided means of quickly analyzing herbicidal oils, and of identifying them sufficiently well so that their characteristics may be correlated with results on track.

Recognizing the limitations of the weed killers available today, advantage should be taken of those conditions under which a particular formulation will work best. To this end, it is advisable to make a survey of the condition of vegetation along the roadway prior to spraying. This survey would aid in determining the type and approximate amount of herbicide which would be required to cover the area to be treated. Often a great saving is possible by determining what areas should be treated, and locating weed-free areas which do not necessarily need treatment. Control of rates, time of application, and type of treatment, under system-wide jurisdiction of trained personnel, is valuable.

This report is presented as information only.

CHAIRMAN CROSLAND: We now turn to the report on Assignment 6, which special studies had to do with roadway formation and protection. The report will be rendered by its chairman, L. D. Shelkey, assistant engineer, Bessemer & Lake Erie Railroad. At the conclusion of his report, Mr. Shelkey will introduce the speaker I referred to previously.

Assignment 6—Roadway: Formation and Protection, was presented by Subcommittee Chairman L. D. Shelkey (Bessemer & Lake Erie).

MR. SHELKEY: Mr. President, members and guests: Your committee reports this year on both of its assignments, with the report on Assignment (a), Roadbed Stabilization, being submitted in two parts, designated as Part 1 and Part 2.

Part 1 presents, as information, construction data for the successful stabilization of a relocated railroad embankment by the installation of a system of vertical sand drains and by subjecting it to an overload of fill for some months.

Part 2 is a report on soil stabilization by the electro-osmosis process. It is presented as information, with the thought that it may serve to suggest the desirability of an actual, initial installation in a railroad fill for experimental purposes.

Parts 1 and 2 were prepared by Dr. R. B. Peck, research professor of foundation engineering at the University of Illinois. This work, under committee sponsorship, is part of the cooperative investigation of the Engineering Division and the Engineering Experiment Station of the University of Illinois, under the direction of G. M. Magee, director of engineering research, AAR, and Dr. Peck.

The report on Assignment 6 (b), Construction and Protection of Roadbed Across Reservoir Areas, was last published in the Proceedings, Vol. 56, 1955, pages 706–711, incl., with the intention that it would be presented for adoption as Manual material in 1956.

Mr. President, this assignment, as authorized by the Board Committee on Outline of Work, is entitled, "Construction and Protection of Roadbed Across Reservoir Areas; Specifications." Since the material is essentially in the form of recommended practice

rather than specifications, your committee feels that the word, "specifications", should be deleted from the title. With that understanding, I move that the material appearing in last year's report be approved for publication in the Manual immediately following page 1–1–36.

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. Shelkey: This concludes the report on Assignment 6.

Many of us have been or will be confronted with the problems resulting from landslides. Your committee is pleased to have the privilege of presenting to this Association an address by one who has an intimate knowledge of these problems. Our speaker, with a background of 25 years of experience in the observation of land formations and movements all over the world, is Mr. Edwin B. Eckel, chief of the Engineering Geology Branch of the U. S. Department of the Interior, Geological Survey, who will address us on the subject, Landslides and Their Significance to Engineers. Mr. Eckel. [Applause]

Landslides and Their Significance to the Engineer

By Edwin B. Eckel

Chief, Engineering Geology Branch, U. S. Geological Survey

The significance of landslides to the engineer can be stated very simply—they can mean constant headaches to the design, construction or maintenance engineer; they occasionally cost lives; and they cost a great deal of money.

Comparatively few lives are lost because of landslides in the United States, but there have been many classic slides in China, in Scandinavia, in the Alps, and elsewhere that have killed scores and even hundreds of people. The difference in death toll between the United States and some of these countries is not that we have fewer slides, or know how to control them any better; I think it's simply because the landslide-susceptible parts of our country are not as thickly populated as they are in many other countries.

Even though our landslides have not killed many people, they are expensive. The average yearly cost of landslides in the United States runs to hundreds of millions of dollars. This money, paid out every year by taxpayers or private companies, includes not only the direct costs of corrections and repairs of damage caused by landslides, but also very large sums for delays of traffic, interruptions of service, and claims for damages.

Highways, railroads, and pubilic utilities receive the greatest direct damages. Heavy losses are also sustained by local governments and by homeowners in some cities. Many farms, resorts, and summer homes are destroyed by slides, particularly along the shores of rivers, lakes, and bays.

Most of the material in this paper is condensed from a volume on Landslides and Engineering Practice that is being prepared by a Highway Research Board committee on landslide investigations. A nationwide questionnaire that we used to gather much of the material for our book brought together some of the typical costs of landslides. Thus, one state highway department reported annual costs of more than $1 million, three states spend between $500,000 and $1 million each year, and six other states more than $100,000. These figures apply very largely to maintenance costs, because highway department figures for reconstruction and damage claims are not easily available.

Railroads, on the other hand, have much more complete cost figures. If the railroads that answered our questionnaire can be assumed representative from the standpoint of landslide problems, the direct costs of landslides to the United States and Canadian rail-

Fig. 1—Aerial view of disastrous slide at Nicolet, Que., during November 1955. The town is built on sensitive marine clays such as characterize much of the St. Lawrence Valley and parts of Scandinavia. Without warning, and for causes that are little understood, the ground became almost liquid and rushed out toward the river (beyond left of picture). Property damage amounted to several million dollars. Photograph by Montreal Gazette.

road systems amounts to well over $5 million per year. Indirect costs, moreover, such as damage to equipment and lading, would far more than double this figure.

It is important to remember that it is not necessarily the big landslide—the "moving mountain" that makes the newspaper headlines—that causes the most trouble or that costs the most money. A single rock falling from a cliff can wreck a train just as effectively as a major slide. An insignificant little earthslide that sloughs off into the ditch along a railroad track or a highway can, if it is continuous, run up an enormous bill for maintenance costs.

There are many kinds of landslides. They involve hard rocks as well as soils; they range in speed from almost instantaneous to extremely slow; they occur on steep cliffs and also on nearly horizontal slopes. All landslides, however, whatever their classification, involve the failure of natural materials under shear stress. The causes of all landslides, then, are due either to factors that increase shear stress or to those that decrease shear strength.

Removal of lateral or underlying support, as by erosion or by man-made cuts, addition of weight from water or by means of fills or buildings, vibrations due to earthquakes, explosions or passing trains—all these can cause landslides by increasing shear stresses.

Changes in the initial state of the material, as by chemical weathering, increase in pore pressures by addition of water, or the presence of inherently weak or fractured materials, are among the factors that mean low shear strength, hence that can lead to landslides if the materials are disturbed in any fashion.

Fig. 2—Debris slide along the Great Northern Railway (near head of slide area), Kettle Falls, Wash. The slide passed over the highway at base of slope and into Lake Roosevelt, creating a destructive wave. It has been partially corrected by excavation of the toe. This is one of hundreds of slides, some of them enormous, that have occurred along the shores of Lake Roosevelt, behind Grand Coulee Dam. It is still difficult or impossible to predict when slides will occur, but geologic studies, supplemented by statistical methods, make it possible to outline areas where future slides are most likely to take place. Photograph by F. O. Jones, U. S. Geological Survey.

There are innumerable methods of preventing or correcting landslides. The most certain method, perhaps, is avoidance—to go around or over the actual or potential slide. Unfortunately, this method is not always feasible because of economic or other reasons.

All the other available methods of prevention or correction depend on treating one or both of the two principal causes of slides—increased shear stress and decreased shear resistance. That is, corrective or preventive methods seek to *decrease* the shear stress in the materials or to *increase* their shear resistance.

Some methods can accomplish both objectives at the same time. Subdrainage, for example, decreases shear stress by removing the weight of contained water; it also increases shear resistance by removing the lubricating, pore pressure, and other effects of the water in the soil.

Drainage of surface and subsurface water is, in fact, one of the most effective methods of treating almost all kinds of slides; it is nearly always used in conjunction with other methods.

Shear stresses can be reduced in a number of other ways than by drainage. In some cases, weak materials are entirely removed, along with the activating forces they have been imposing. More commonly, however, shear stresses are reduced by some form of unloading of the upper parts of a slide. This is done by cutting back the slope, by removing its top, by benching, or by other means.

Shear resistance can also be increased in many ways. Subdrainage, again, is one of the most effective means. Restraining structures of all kinds—piling, tie rods, retaining

Fig. 3—Aerial view of Cedar Creek slide, on Denver & Rio Grande Western Railroad near Montrose, Col. The slide consists of a series of slumps with earthflows at the toe. The material is Mancos shale overlain by 10 to 20 ft of gravel. The tracks have been pushed out several times and the new alinement is again being covered by an earthflow. Relocation of the railroad to the other wall of the valley could have solved the problem. Otherwise, correction of the slide would have required removal of irrigation water from the gravel-capped mesa at left, partial removal of the upper part of the slide, subdrainage, and possibly by loading of the toe. Actually, the line has now been abandoned. Photograph by R. W. Fender, Montrose, Col.

walls—operate on the principle of increasing the forces that resist down-slope movement. Among some of the more promising methods for the future are chemical or electrical treatment of soil to increase its rigidity.

The point is that nearly all slides, actual or potential, can be corrected or prevented. To be effective, the design of a corrective structure must be based on thorough knowledge of the nature, history, and geologic causes of the slide. Beyond the limits imposed by this knowledge, the choice of method, and its actual design, is almost entirely a question of economics. Preliminary designs, for instance, may show that one method is far cheaper than another. On the other hand, the engineer may find that any available method of correction is too expensive. In this case he may have to decide on a partial correction, or one none at all, knowing when he does so that he is running up a big maintenance bill for future years.

Now, a few words on what we still need to know about landslides. We have a workable classification of landslides; the processes that cause them are well understood; we

know dozens of methods for preventing or correcting slides; we know, at least in general terms, where slides are most likely to occur, in what parts of the country and in what kinds of rocks and soils.

What do we not know? It seems to me to boil down to this—we need to know much more about when and where the next slide is going to occur and we need to know more exactly what treatment to apply to a given slide, potential or actual.

To answer these needs is not a simple job, but it can be done if enough engineers and geologists realize the economic importance of the landslide problem, make opportunities to study it, and record their results.

We need many many more studies of actual slides—not simply descriptions of their size and shape and the damage they did. To get much farther with our understanding of slides these descriptions must include detailed records of the physical properties of the soils or rocks that were involved, detailed histories of the movements that took place, and enlightened inquiries into the causes of movement. With this kind of facts we can go a long way in comparing slides and in extrapolating the knowledge thus gained to the solution of new slide problems.

Another large gap in our knowledge has to do with the real meaning of shear and other tests that are performed in the laboratory. These test results mean nothing in themselves—they must be correlated with field behavior to have any value. The Japanese have made real progress in this direction. They use strain gages that are correlated with the results of soil laboratory tests to give warning of imminent slides along their railroads. We have done little of this kind of work in the United States, but we must do it if we want our laboratory work to mean anything.

Finally, we need to record many more of our failures as engineers or geologists. The literature is full of descriptions of preventive or corrective methods that were successful. On the other hand, records of installations that failed to do the job expected of them are notably lacking. Nobody enjoys publicizing his mistakes, of course, but just the same there is little hope of improving our knowledge of how to handle landslides until we are able to study and compare the case histories of methods that have failed with those that have been successful.

Chairman Crosland: On behalf of the Association, and especially Committee 1, Mr. Eckel, I wish to thank you for a very interesting and most instructive talk.

Now we're coming to the end of our presentation, and this is also the "end of me." I am retiring as chairman, but before I do, I would like to take just a few minutes to introduce to you the new chairman and vice chairman of this committee who are taking over as of now.

B. R. Meyers (Chicago & North Western): Mr. Crosland, I have a question before you go into your speech.

On page 648, under your specifications for pipe line crossings, the statement is made that "Longitudinal occupancy of railway right-of-way is highly objectionable and must be avoided where possible." I'm not taking any issue with that statement, but there has been some interest expressed in this matter by various companies that use railroad rights-of-way for pipe lines, cross-country. There has also been some pressure brought to bear to allow pipe lines on railroad rights-of-way in getting into large metropolitan areas.

Now, maybe you have already done this, but if you haven't, I think it would be beneficial to the Association to have some information some place in the record—Bulletin or Proceedings—as to why that statement is in here. I mean, there are so many things

that tend to point to the location of pipe lines or railroad rights-of-way, that we will all be facing this problem in the near future.

Chairman Crosland: Thank you, Mr. Meyers.

Actually, I think the reason that statement is in there is because of the potential hazard with flammable substances carried on the right-of-way. It is rather difficult to use a right-of-way for railroad purposes and also for pipe lines carrying flammable substances. However, I think your point is well taken, and probably we should do some more study on it. We know that some railroads are deliberately building pipe lines on their rights-of-way.

Thank you for your remarks. I will turn the question over to our subcommittee for a little more elaboration the next time.

If there are no further questions, I'll proceed with my introductions.

Mr. A. P. Crosley, engineer maintenance of way, Reading Company, is succeeding me as chairman. Mr. Crosley, will you stand and be recognized? [Applause]

Mr. G. B. Harris, assistant engineer of the Chesapeake & Ohio is the incoming vice chairman. Mr. Harris, will you please stand? [Applause]

Mr. President, that concludes the report of Committee 1.

President O'Rourke: Thank you, Colonel Crosland, for "firing all guns" for us here, with another most interesting report by your committee.

Thank you, Mr. Eckel, for your interesting presentation on landslides and their significance to engineers. Indeed, landslides present us with serious problems.

Colonel Crosland, we appreciate the aggressive and effective way in which you have directed the work of Committee 1 during the past three years, during which period your committee has made significant contributions to the work of the Association and our members.

We are glad to welcome, as the new chairman of your committee, Mr. A. P. Crosley, engineer maintenance of way of the Reading Company, and as the new vice chairman, Mr. G. B. Harris, assistant engineer, Chesapeake & Ohio. We are sure that in these two men you turn the direction of your committee over into capable hands.

Your committee is now excused with the thanks of the Association. [Applause]

The next and final report of our technical committees is that of Committee 4—Rail, the chairman of which is Mr. B. R. Meyers, chief engineer, System, Chicago & North Western Railway.

Discussion on Rail

[For report, see pp. 783–883.]

[President G. M. O'Rourke presiding.]

Chairman B. R. Meyers (Chicago & North Western): Mr. Chairman, members and guests: Because our time has run out on us, and because of commitments this afternoon for the ground-breaking ceremonies at the AAR Research Center, we will dispense with reporting on our various assignments with the exception of that on Manual revisions and two other short items. I will ask each subcommittee chairman, when our report is finished, to please give his remarks to Secretary Howard, so they can be published in the Proceedings, where you can read them later.

Report of Committee 4 starts on page 783, Bulletin 528, and includes reports from 9 of the 11 subcommittees.

It is with deep regret that we report the death of Mr. G. W. Harris, retired chief engineer of the Santa Fe System, and a long-time valuable member of this committee. A memoir on Mr. Harris has been prepared and will appear with our report in the Proceedings.

MEMOIR

G. W. Harris

G. W. Harris, retired chief engineer system of The Atchison, Topeka and Santa Fe Railway Company, died at Los Angeles, Calif., on December 21, 1955. He is survived by his wife, Maud Leslie Harris.

Mr. Harris was born in Neosho Rapids, Kans., on March 7, 1878, and entered Santa Fe service as a rodman at Winslow, Ariz., in February 1898. He rose progressively through various positions in the Engineering Department until he became an assistant engineer at Pueblo, Colo. Throughout those earlier years he was particularly interested in construction activities.

About that time, the Santa Fe was embarking on one of the largest construction programs in its history, and Mr. Harris' talents in the construction field were recognized by the management. As a result, in 1906 he was promoted to the position of assistant engineer-in-charge-of-construction for two of the Santa Fe's subsidiary companies: the Pecos and Northern Texas and the Southern Kansas Railways of Texas.

Mr. Harris was appointed chief engineer of the Coast Lines Grand Division of the Santa Fe west of Albuquerque, N. M., in 1912. While on this assignment the Santa Fe was engaged in a program of building considerable mileage of second track in this territory. As chief engineer, Mr. Harris located and constructed a large portion of this second track mileage on divergent lines to secure the most favorable grades in both directions.

During federal control of railroads, Mr. Harris served as corporate chief engineer of the Santa Fe, and when the railroads were turned back to their owners, he was appointed assistant chief engineer system, becoming chief engineer system in November 1927. As chief engineer system, his interest in the treatment of ties and timber, and his encouragement of experimental work in these lines, lead to numerous improvements in the treating processes on the Santa Fe. He was also vitally concerned with developing improvements in the design and metallurgy of rail and other track materials, and his enthusiasm in this respect was reflected in meetings of the Rail committee of the American Railway Engineering Association, of which he was a member from 1930 until his retirement from railroad service in 1948.

Mr. Harris joined the American Railway Engineering Association in 1911 and became a Life Member in 1946, serving as a Director from 1930 to 1932. In addition to his long service on the Rail committee, he also served as a member of Committee 23—Shops and Locomotive Terminals, from 1921 to 1929, and as a member of Committee 12—Rules and Organization, in 1939 and 1940.

Through his professional attainments in construction and general railroad engineering Mr. Harris contributed greatly to the success of the railroad with which he was identified, and this, together with his sound judgment, administrative ability, generous nature, and loyalty to his fellow workers, earned him the respect and friendship of all his associates.

Chairman Meyers: Now I will ask L. S. Crane, chairman of Subcommittee 1—Manual, to give his report.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman L. S. Crane (Southern).

Mr. Crane: Mr. President and gentlemen: The Rail committee recommends that a 140-lb headfree joint bar, detailed plan of which is shown in the Bulletin, be adopted as an AREA standard and included in the Manual as a part of "Joint Bars and Assemblies". I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

It is recommended that the Specifications for Open-Hearth Steel Rails, dated 1954, be reapproved, with the following modification in Par. 17 (e):

"All rails of a heat in which both the carbon and manganese content are above the mean of the specification range shall have both ends painted blue."

It is recommended that paragraphs 18 (a) and 18 (b) of the Specification for Open-Hearth Steel Rails, 1954, be modified to read as follows:

(a) "No. 1 rails with carbon and/or manganese content below the mean of the specified range shall be loaded in separate cars."

(b) "No. 1 rails with carbon and manganese content above the mean of the specified range shall be loaded in separate cars."

I so move.

[The motion was regularly seconded, was put to a vote and carried.]

It is recommended that Form 402–c (a)—Instructions for Filling in Rail Failure Forms 402–C and 402–L be reapproved with the following revisions:

Modify Par. 13 to show 140 RE section in lieu of 140 PS section.

Add to the tabulation 119 CF&I and 136 CF&I sections with weights as shown in the Bulletin.

I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

It is recommended that the document on page 4–M–1 of the Manual, "Application of Welded Bonds," be reapproved with the following revision:

Change heading to read "Application of Rail Bonds."

I so move.

[The motion was regularly seconded, was put to a vote, and carried.]

Mr. President, that concludes the report of Assignment 1.

Assignment 2—Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest, was presented by Chairman Meyers.

Chairman Meyers: Is Professor Cramer here? Professor Cramer is research associate professor, University of Illinois. I would like to have him give us about two or three minutes' comment on failures in control-cooled railroad rails.

Investigation of Failures in Control-Cooled Railroad Rails

By R. E. Cramer
Research Associate Professor, University of Illinois

During the past year 43 failed control-cooled rails were sent to our laboratory for examination to determine the cause of failure.

Slide 1 (see Table 1, page 788 of the Proceedings) gives a summary of these failures. The most notable feature of this table is that there were no transverse fissures from

shatter cracks this past year. This shows how well the control cooling is being done by the rail mills.

You will note that there were:

8 Transverse fissures from hot torn steel.
24 Detail fractures from shelling.
5 Fractures from welded engine burns.

The remaining failures were one each of head and web separation; engine burn fracture; bolt hole fracture; shelling failure; detail fracture from head check; and web failure at stamped heat number.

Slide 2 (see Fig. 1, page 790 of these Proceedings) shows the fractures of two transverse fissures from hot torn steel and etched longitudinal slices from each rail. The fracture at the top left shows that the rail head contained large porous holes where the metal pulled apart during rolling because it was too hot for satisfactory rolling. The etched slices show the porosity along a slice from each rail head.

Slide 3 (see Fig. 2, page 791 of these Proceedings) shows a fracture at welded engine burn on the top right and an etched slice on the top left through a welded engine burn. The two photomicrographs on the bottom at 50× magnification show our method of determining what caused the weld to fail. It is well known that most engine burns that are repaired by welding do not fail, but in the case of the left photomicrograph we found the large dark spot to be porosity in the weld metal from which the failure started.

In the right photomicrograph a crack from the original engine burn was not removed by grinding before the rail was repaired by welding and this is considered to be the reason the transverse failure developed.

The rail in Slide 4 (see Fig. 3, page 793 of these Proceedings) shows a head and web separation crack starting to form at the rail end in an insulated joint. It is typical of 432 such failures found, all in insulated joints, in 180 miles of track on 1 railroad. This failure is typical of a corrosion fatigue crack as shown by the photomicrograph in the lower part of the slide where the cracks are magnified 80 times. The dark material along the cracks is the iron oxide caused by corrosion.

In closing, let me emphasize the record that there were no transverse fissures from shatter cracks and no shatter cracks were found in any of the rails examined last year.

Chairman Meyers: The only other item that I would like to bring to the attention of the members is tests of rail joint impact effects, as reported on under our Assignment 10. I am not bringing this up because the tests were made on our railroad.

Mr. Magee, would you say a few words, and highlight the results?

Tests of Rail Joint Impact Effects

By G. M. Magee
Director of Engineering Research, AAR

I would like to discuss first the study of joint gap measurements reported in Appendix 10–a (page 860) and made by our research staff on the two service test installations of 78-ft rail, one for 115 RE section on the Chicago & North Western Railway and one for 133 RE section on the Pennsylvania Railroad.

Fig. 1 (page 861) shows the joint gap measurements taken during summer and winter weather conditions on the Pennsylvania installation. A comparison is given for both 39-ft and 78-ft rail. The same information is shown in Fig. 2 (page 862) for the C&NW

test. The principal objective in these measurements was to determine whether there was any substantial difference in the number and amount of joint gap openings for the 78-ft rail compared to the 39-ft rail, especially during the low temperatures in winter. We were fortunate in obtaining these measurements at about 10 deg below zero on the C&NW test, and it will be observed for both the 39-ft and 78-ft rail that there was a considerable number of joints found with the gap beyond 0.375 in, which is the maximum joint gap possible without bending of the bolts. Although there was indication of a somewhat larger gap opening with the 78-ft rail, it was by no means in relation to the increase in rail length, and it appeared that this condition could be improved materially if the rail was laid originally with considerably less expansion allowance.

To make a further study of this condition a theoretical consideration is presented in the report showing the calculated expansion movements that would be expected in 78-ft rail, taking into account the restraint to rail end slippage offered by the frictional resistance of the joint bars. For example, it would theoretically require a temperature change of about 35 deg to move the rail ends within the joint bars in either direction, and a temperature range of 70 deg without any rail end movement could be anticipated. A theoretical diagram of joint gap opening with respect to temperature change is shown in Fig. 3 (page 863) in which the openings measured in the two service tests are shown in comparison with the theoretical openings. Additional measurements that have been made since this report was prepared have indicated that this theoretical consideration is all right so far as it goes, but it needs to be expanded to take into account the rail creepage forces that develop during train movements, which will tend to slip the rail ends in the joint bars even when the temperature forces are not sufficient to cause slippage. This is being given further study and will be reported on further next year.

In Appendix 10–b there is given the results of tests conducted on the C&NW to determine the impact effects on the joint ties due to joint gap and rail end batter at rail joints. It was thought that information developed from these tests would be helpful in evaluating the economics of 78-ft rail in that it would develop information on the added load placed on the joint ties due to impact effects associated with the use of rail joints and which could be eliminated at one-half of the joints by using 78-ft rail. A special test train was used, consisting of a single diesel unit pulling a passenger car and three box cars equipped with high-speed trucks. The box cars were loaded with different weights so that results were obtained under heavy, medium and light wheel loads. Test runs were made at speeds of from 5 to 90 mph. As a matter of expediency, since rails rolled to 78-ft lengths were not available, two 78-ft lengths of rail formed by butt welding 39-ft lengths together were utilized. By means of electrical strain gages fastened on the bottom surface of the tie plates and accelerometers placed on the joint ties, it was possible to measure the applied tie load and rate of tie acceleration under good rail joint conditions, with little batter and a good fishing surface fit; under poor joint conditions, with a large amount of batter and worn joint bars; and under butt welds.

One rather interesting development from the test was that the butt weld did not entirely eliminate the impact effects because there was some irregularity in grinding the running surface and a slight depression at, and extending several inches each side of, the weld resulted in some impact effect.

The results obtained in the tests are given in tables and diagrams in the report, but the principal conclusions can be summarized by saying that the added load on the joint ties due to impact effects was on the order of 5 percent for both the good joint conditions and the butt welded rail. With the bad joint conditions the impact effects approxi-

mated 60 percent added load on the joint ties. This information is helpful in evaluating the economics of 78-ft rail or even continuous welded rail, because an estimate of the cost to maintain the rail ends and joint bars in the good joint condition would closely represent the benefits that are obtainable with elimination of rail joints by butt welds. With 78-ft rail this saving would, of course, apply to one-half of the rail joints.

[Following are the reports on Assignments 3, 4, 5, 6, 7, 8, 9, 10 and 11 which time did not permit presentation to the annual meeting.]

Assignment 3—Rail Failure Statistics Covering (a) All Failures; (b) Transverse Fissures; (c) Performance of Control-Cooled Rail. Subcommittee Chairman C. J. Code, assistant chief engineer—tests, Pennsylvania Railroad.

Rail Failure Statistics

By G. M. Magee
Director of Engineering Research, AAR

The purpose of these statistics is to indicate the extent of control of the transverse fissure problem that has been obtained by the use of control-cooled rail and detector car testing; to give data on the quality of each year's rollings for the various mills; and to show the types of failures that are occurring on the various railroads as related to the mill producing the rail. They represent the performance on approximately 90 percent of the main-line track in the United States and Canada.

This year's report included rail failures reported to December 31, 1954. It is indeed gratifying to note the service transverse fissure failures decreased in 1954 to a new low of 913, considering that 7795 such failures were reported in 1943, and have been on a more or less steady decline ever since. This is a record of which we can indeed be proud.

The reports of the number of failures in control-cooled rail that occurred during the first 10 years of service, which we consider indicative of rail quality, continue to show a good performance in general. A few of the mills have a failure rate above normal for certain year's rollings, but investigation has indicated this is due to local conditions that occurred and the performance in general is quite good with respect to the types of failures that have occurred in control-cooled rail.

Web failures within the joint bar limits, and detailed fractures from shelling are the two outstanding types of failures, representing 35 percent and 38 percent, respectively, of all failures reported. It is believed that the new rail sections and bolt hole spacings will be effective in reducing the number of web failures within the joint bar limits so that detailed fractures from shelling spots is indicated as the remaining type of failure of most concern. The number of transverse fissure failures that have occurred in control-cooled rail continues to be negligible.

Assignment 4—Rail End Batter; Causes and Remedies. K. K. Kessler, engineer physical tests, Baltimore & Ohio Railroad, chairman. (No report).

Assignment 5—Economic Value of Various Sizes of Rail. Subcommittee Chairman J. C. Jacobs, engineer maintenance of way, Illinois Central.

Mr. Jacobs: There is a typographical error appearing on page 815 under the 131-lb rail heading. The south limit of the 131-lb test is at M.P. 152.24, instead of 154.24, as printed in the text.

The report is a continuation of Study A reflecting changes in the test mileage and computed to show averages after 11 years. The original estimate of service life in first location was 15 years for the 112-lb rail and 25 years for the 131-lb rail. However, it now appears that 14 years for the 112-lb and 20 years for the 131-lb will be more nearly accurate, and computations have been revised accordingly. The study will be continued, and this report is submitted as information.

Assignment 6—Service Tests of Various Types of Joint Bars. Subcommittee Chairman T. A. Blair, chief engineer, Santa Fe System. (No report).

Assignment 7—Joint Bar Wear and Failures; Revision of Design and Specification for New Bars, Including Insulated Joints, and Bars for Maintenance Repairs. Embert Osland, office engineer, Santa Fe, subcommittee chairman.

Mr. Osland: The principal work on the assignment during the past year has been continuation of the rolling-load tests of joint bars at the University of Illinois, under the direction of Professor R. S. Jensen. Arrangements have been made to run rolling-load tests on bars with various shapes and sizes of head easements. During the year, rolling-load tests were extended to include compromise joints, with the view of determining whether any improvements could be suggested in present designs or metallurgies. The results of these tests are submitted in Appendix 7–a.

Previous rolling-load tests have indicated a definite relationship between the Brinell hardness and the number of cycles to produce failures; also, the history of failed bars in service indicates that the large majority of the failed bars have not come up to the physical requirements of the specifications. Since there is a definite relationship between the Brinell hardness and the tensile strength, we proposed to representatives of the steel mills at the Joint Contact Committee meeting at Williamsburg, that consideration be given to taking a number of Brinell hardness tests in lieu of a portion of the tensile strength tests now required by the specifications. We also suggested that some thought be given to the installation of radiation pyrometers just ahead of the quenching baths. The matter will be given consideration by the steel companies in a report rendered next year.

This concludes this report, which is submitted as information.

Assignment 8—Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention. Subcommittee Chairman L. S. Crane, engineer of tests, Southern Railway System.

[No oral report was made on this assignment, but subsequent to the annual meeting, attention was called by Professor R. E. Cramer to the following error in Appendix 8a, Fourteenth Progress Report on Shelly Rail Studies at the University of Illinois: In Table 1 on page 851, Bulletin 528, the tensile strength value of specimen 1151A* should have been shown as 177,000 psi instead of 117,000 psi.]

Assignment 9—Recent Developments Affecting Rail Section. Subcommittee Chairman W. J. Cruse, engineer maintenance of way, Great Northern Railway.

Mr. Cruse: The study of the redesign of 100 RE rail and joint bars to conform with the 115 RE and 132 RE rail and joint bars was discontinued following a canvass of chief engineers of member roads which disclosed that less than 2 percent would use this rail if available.

A survey of the proposal for the adoption as an AREA standard of a headfree joint bar for the 140 RE rail section has been completed. This headfree bar is for use as an alternate for railroads desiring a headfree bar in preference to the head-contact bar.

An investigation of a velocity power punch for punching holes in rail was made. Also, tests made at the AAR Research Center with the Sonntag fatigue testing machine of a piece of 115-lb rail in which holes had been punched by the TP&W forces at low temperature, showed excellent results. The fatigue strength of the specimen so punched was higher than that of a similar specimen in which the holes had been drilled.

Earlier investigation at the Pennsylvania Railroad laboratory at Altoona had shown cracks in the rail web of 100-lb and 112-lb rails punched at low temperature. No fatigue tests were included in this investigation.

In view of these conflicting results, additional rails were punched in September 1955. These tests were conducted by the Pennsylvania Railroad laboratory personnel under C. J. Code's supervision and were witnessed by G. M. Magee, director of engineering research, AAR, and Mr. Bolda of the Southern Railway. The velocity power punch was operated by representatives of the manufacturer. All rails were of 100-lb PS section, 6 ft long. Three holes were punched in each end of each piece. There were two new open-hearth rails with sawed ends and two new open-hearth rails with torch cut ends. The rails were of two different heats.

Cracks were developed in the rail web of three of the four rail ends which had been torch cut and which were punched at temperatures of 0–64 deg. One rail end punched at 15 to 19 deg developed no cracks.

Cracks were developed in the pieces of rail with sawed ends punched at —12 to 0 deg and in one end at 16 to 29 deg. No cracks were developed in another end at 25 to 29 deg, or in another at 61 to 62 deg. All temperatures reported are Fahrenheit.

In view of these results, representatives of the manufacturer are working on improvements in this tool which will better support the rail web on the side opposite the punch, and it is hoped that these will eliminate the cracks. When the improved velocity power punch is ready, tests will again be made.

This report is presented as information.

Assignment 10—Service Performance and Economics of 78-Ft Rail, Collaborating with Committee 5; Specification for 78-Ft Rail. Subcommittee Chairman L. R. Lamport, chief engineer maintenance, Chicago & North Western System.

Mr. Lamport: The report on Assignment 10 is a progress report, submitted as information.

Your committee was not able to prepare specifications for the rolling of rail in 78-ft lengths in time to submit to this meeting, but is now studying those specifications prepared by the steel company representatives. It is believed that, with minor changes, a submission of specifications for consideration and approval, can be made at the 1957 convention.

It is worthy of note that the Burlington Railroad installed 99 track miles of 78-ft rail in 1955, making a total of 236.7 miles now in track on that railroad.

The Engineering Division research staff of the AAR, under the direction of G. M. Magee, has carried out a very interesting study of joint gap measurements under high and low temperature extremes on both 39-ft and 78-ft rail on the Pennsylvania Railroad near Hammond, Ind., and on the North Western Railway near Calamus, Ia. This report should be of much interest to all, whether or not we are laying 78-ft rail, and your committee is pleased to include it as Appendix 10–a.

Appendix 10–b covers the very interesting joint impact tests, also carried out by the Engineering Division research staff of the AAR, on the North Western Railway near Clinton, Ia.

[For further comment on these tests, see earlier remarks in the convention report of Committee 4, by G. M. Magee, under the heading "Tests of Rail Joint Impact Effects."]

Assignment 11—Rail Damage Resulting From Engine Burns; Prevalence; Means of Prevention; Repair By Welding. Subcommittee Chairman J. C. DeJarnette, Jr., chief engineer, Richmond, Fredericksburg & Potomac Railroad.

Mr. De Jarnette: Your committee has canvassed all railroads reporting rail failure statistics as to the extent of their practice of welding engine burns, and failures experienced therefrom. Eleven railroads reported that prior to December 31, 1954, they had welded 255,889 engine burns, and that during 1954 they had experienced nine failures.

Your committee is also accumulating information on means of prevention and methods of repairing engine burns by oxyacetylene welding.

Chairman Meyers: Mr. President, the shortening of our presentation does not mean that we didn't do our full measure of work during the past year, or that these isn't a lot of "meat" in the report of our committee as published in the Bulletin.

This concludes the report of the Rail committee.

President O'Rourke: Thank you, Mr. Meyers, especially for your effort to speed up the convention presentation of your committee. I am sure that our members will want to read the detailed reports of your committee as presented in the Bulletin.

We are indebted to you and your committee for the highly informative reports and Manual recommendations which you bring to us each year with respect to the all-important subject of rail, joint bar assemblies and related matters. We appreciate the work which is being done under your direction, and the cooperative efforts of Mr. Magee and his staff, and of our friends at the University of Illinois.

Your committee is now excused with the thanks of the Association. [Applause]

The presentation of the report of the Rail committee completes the formal presentation of our committee reports at this annual meeting. I am sure that the many reports, papers, addresses and panel discussions which have been presented to us during the past two and one-half days have been of great value to all of us in attendance, which value will continue to our membership generally, and the railroads, through the transcript of the entire convention, which will appear in the 1956 Proceedings of the Association.

So, my many thanks to everyone who has participated in the program of this convention, and to all of those who have contributed toward the work of the Association during the past year.

Closing Business

I now call to order the closing business session of this convention. Is there any other busniess to come before us?

C. H. Mottier (Illinois Central): Mr. President, may I have the privilege of the floor? George, just one year ago you and I stood on this same platform on the occasion of your installation as president. On that occasion, as the representative of your friends and associates on the Illinois Central, and as evidence of their esteem, I presented to you a gavel, which at the time I said was an emblem of the authority of your office. You referred to it, as you may remember, as an Irish shillelagh.

On this occasion I am here for a different purpose—to help usher you out of the presidency and to introduce you into membership of the Past Presidents' Club, which is a very distinguished, dignified and intelligent group. I am sure you will add to the distinction of that group.

Some people have been so rude as to refer to us as a bunch of has-beens, but I'm sure that you and I will agree that it is a very dignified and intelligent group.

And I want to say, also, on behalf of your friends, and associates, we wish to congratulate you on the fine work you have done this year. You have handled this job with credit and distinction to yourself and your Irish belle, and also to your friends on the Illinois Central.

You are now the junior member of our past president's group, but I wish that you and your good wife may live many, many years, until you can probably say that you are the senior member of that group.

And now, I want to assume another role as representative of the officers and members of this Association, and present you with this plaque as an expression of appreciation for the work you have done for this Association. I will read the inscription on it: "The American Railway Engineering Association records its grateful appreciation to George Martin O'Rourke for his able administration of the affairs of the Association during his term as President, 1955–1956."

I want to say that I never before knew that his name was George Martin. We always used to call him George Mike O'Rourke. [Laughter]

George, I'm glad to give this to you. I know you will accept it as a permanent record of our appreciation, and something you can point to with pride to your grandchildren and great grandchildren, showing them what a distinguished individual you were. [Applause]

PRESIDENT O'ROURKE: Thank you, Mr. Mottier. To you, sir, and to the members of the American Railway Engineering Association, I humbly but happily, and with great sincerity, express my appreciation for this beautiful plaque. It will be hung with others received from the National Railway Appliances Association and from the Illinois Central Railroad—the latter for 50 years of continuous service. Mrs. O'Rourke—my Irish belle—and I shall cherish it always, and look back upon this occasion as one of the happiest of a happy life.

The close of our annual meeting brings with it not only satisfactions, but some regrets, for each year the close of our meeting brings to an end the service of several members of the Board of Direction.

This year the annual meeting marks the end of service on the Board of Past President C. G. Grove, area engineer of the Pennsylvania Railroad, under the established plan wherein past presidents remain on the Board of Direction for only two years following the completion of their term of office as president.

The Association is deeply indebted to Mr. Grove for his long, interested and valuable service to it in an official capacity, and in his leaving the Board we shall miss his always wise counsel and advice. I shall be greatly pleased if Mr. Grove will stand and be recognized. [Applause]

The terms of office of four other members of the Board of Direction also terminate with this annual meeting. These members are: E. S. Birkenwald, engineer of bridges, western lines, Southern Railway System; H. B. Christianson, Sr., special engineer, Milwaukee Road; G. E. Robinson, engineer of structures, New York Central; and B. R. Meyers, chief engineer, system, Chicago & North Western. All of these men have rendered great service to your Association in their official capacities on the Board, and words fail me in an attempt to express our appreciation.

Will Mr. Birkenwald please stand? [Applause]

Mr. Christianson had to leave, and Mr. Robinson, because of illness, did not attend the convention except for a few minutes at the Board meeting on Monday.

Mr. Meyers, as I am sure you know, is remaining on the Board in his new capacity as junior vice president, and I will recognize him later.

Because of the shortness of time, I am skipping a lot of the conventional procedure here.

It now gives me great pleasure, as your retiring President, to introduce to you the Association's new officers for the ensuing year.

Our senior vice president for the coming year is Mr. Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad, who, under the Constitution, automatically advances to this position from that of junior vice president. Mr. McBrian, will you please come to the platform?

Your newly elected junior vice president is Mr. B. R. Meyers, chief engineer of the Chicago & North Western System. Mr. Meyers has been a director of our Association since March 1953, and is known to all of you through his other activities in the Association, notably as a member of Committee 4—Rail, of which committee he is at present the chairman. Mr. Meyers, will you please come to the platform and stand here along with Mr. McBrian?

Mr. McBrian and Mr. Meyers, both of you have contributed much to this Association in the past, and I congratulate you upon your further elevation to high office in the Association, with the obligations and opportunities which such affords for still greater contribution to the Association in the future. With men such as you being groomed for the helm, I am sure that we can look with confidence to the future of our Association.

As your president for the ensuing year, you have elected Mr. William J. Hedley, assistant chief engineer, Wabash Railroad. I have asked Past Presidents Chinn and Grove to escort Mr. Hedley to the platform. [Applause]

Past Presidents Grove and Chinn are becoming past masters at escorting prospective presidents to this platform. [Laughter]

Mr. Hedley, it is with pride and pleasure that I proclaim you the newly elected president of the American Railway Engineering Association. Like all of your fellow members, I have the greatest respect for you as a gentleman and an engineer, and I turn over my responsibilities as president to you with the greatest of confidence in your ability to carry forward the objectives of the Association in the year ahead. In so doing, I want to present you with this solid gold emblem of the Association, which bears the engraved words on the back, "William J. Hedley, President, 1956–1957." I hope that you will wear it proudly in the year ahead. I know you will wear it with distinction to yourself and the Association. [Applause]

[President-elect Hedley assumed the chair.]

President-Elect Hedley: Thank you, Mr. O'Rourke. I deeply appreciate the great honor and privilege that is bestowed on me here today. I shall treasure this symbol of that honor, and pray I may prove to be worthy of it.

Yours has been an excellent administration. I shall do my best to carry on in the established traditions you have exemplified so well.

But, my friends, remember always that I will need your help, and will welcome it. I know that I will need but to beckon and call. This is a great team I am on. For me, one of its greatest members is my lady Catherine, who now smiles down on me from the balcony. [Applause] But if I don't seem to sparkle and chime quite so much up here, just remember that although, as Joe Todd said yesterday, I can trace my forebears back to the Seviers of French ancestry, my father was born in England, and so I am but a humble Englishman trying to follow in the footsteps of this man of aplomb, this loquacious Irishman. [Laughter and applause]

W. E. Gardner (Wabash): I'm very pleased to be here to represent your many friends on the Wabash, and to present this gavel to you with our congratulations and

best wishes for your success in handling the affairs of this Association in the coming year. I think you'd like to know that this was made from a cross tie. [Applause]

PRESIDENT-ELECT HEDLEY: Thank you, Mr. Gardner. This is a very fancy piece of Wabash tie right now. It has on it, "William J. Hedley, President, AREA, 1956–1957, from your friends on the Wabash Railroad." I sincerely appreciate this token of support from my fellow members of the Wabash family. The history of its origin will always give me great pride in its possession, and to you, personally, Bill Gardner, I must acknowledge a deep debt of gratitude.

I know this was fashioned in a workshop in which, over the years, you have devoted many, many hours of good and great-hearted effort in the interests of the Boy Scouts, Junior Achievement and other civic affairs. I am honored to be the recipient of one of the excellent products of this workshop.

I will exercise my authority with this gavel at all times in the friendly spirit in which I know it was given by you and the others in the Wabash family, who I see out there as my cheering section in the audience.

J. N. TODD (Southern): Mr. President, may I have the privilege of the floor for a moment? I am speaking on behalf of Committee 14—Yards and Terminals. As the outgoing chairman this year, the committee asked me to present to the new President, and our fellow member, a little token of their esteem.

For many years we have been associated with Mr. Hedley, and we have benefited greatly by his good will and his sound judgment. We now wish to give him a token of our esteem and good wishes. There, Mr. Hedley—Bill—is a traveling case which, by some conspiracy, we believe, is going to suit your needs.

Since a traveling case is not sutiable for inscribing a personal sentiment, we have also secured this small silver tray on which will be inscribed those sentiments which we feel so strongly, representing our personal esteem for you and our good wishes. [Applause]

PRESIDENT-ELECT HEDLEY: Thank you very much, Joe Todd, and all of the members of Committee 14, my friends and associates over a period of 20 years or more.

It is now my privilege and pleasure to introduce to you the four men who were elected as new members of the Board of Direction. As I call their names, I would ask each of them to please come forward and stand in front of the speaker's table.

Mr. G. H. Echols, chief engineer, Southern Railway System. [Applause]

Mr. R. R. Manion, chief engineer, Great Northern. Mr. Manion could not be here, I understand.

Mr. L. A. Loggins, chief engineer, Southern Pacific Lines in Texas and Louisiana. [Applause]

Mr. W. G. Powrie, chief engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad. [Applause]

Gentlemen, I congratulate you upon your election as Directors of this Association. We welcome you to the Board of Direction. It is an office of high honor and responsibility, and I know that you will enjoy your association with the Board, and the Association will benefit greatly from having you on it. [Applause]

Before adjourning our convention, I should like to announce that there will be a meeting of the Board of Direction this afternoon at 3 o'clock, in the Conference Room of the AAR Research Center, following the ground-breaking ceremony at the Center for the new Engineering Building, at 2:30. I hope that many of you plan to be present at this ceremony.

As announced earlier, there is a luncheon immediately, in the Crystal Room, for the officers and members of the Board.

Is there any further business to come before the convention?

There being none, I now declare the Fifty-Fifth Annual Meeting of the American Railway Engineering Association adjourned. [Applause]

[The meeting adjourned at 12:40 o'clock.]

MEMOIR

MEMOIR

Louis Charlton Fritch

Died July 23, 1955

Louis Charlton Fritch, charter member, honorary member, first secretary and eighth president of the American Railway Engineering Association, died at his home in Evanston, Ill., on July 23, 1955. His death severed the Association's last tie to the leadership that brought it into being more than 56 years ago. Mr. Fritch, whose vitality of both mind and body remained singularly unimpaired until but a few months prior to his death and who had attended at least one convention within the past three years, was one of the three railroad engineers who deserve primary credit for making the AREA a reality.

That the Association should have so long enjoyed this intimate contact with the past is to be explained only in part by the fact that this pioneer member was spared until his 86th year; it is to be accounted for also by his early start up the ladder. Entering railway service at 15 as a roadmaster's clerk, he became a division engineer at 23

Louis Charlton Fritch

and a superintendent at 30. What is more remarkable is that he was only 29 when he was included among the small group of representative railroad engineers who were invited by H. P. Robinson, editor of the Railway Age, to attend a conference at the Auditorium Hotel in Chicago on October 28, 1898, to discuss the possibility of creating a new organization which would have the purposes that the Association now serves.

That he evinced on that occasion those qualities of mind and character that were to carry him far in the railroad industry, was demonstrated by his selection from among the 28 present to serve as the temporary secretary, in which position he was required to bear the brunt of the promotional work under the guidance of Augustus Torrey, chief engineer of the Michigan Central, who had been elected the temporary chairman. In Mr. Fritch's own words, "Mr. Torrey may rightfully be called the 'Father of the Association.'" But the task of spreading the word about the proposed organization to the lead-

ing engineers of the railroads and of getting them interested in it by issuing circulars and writing many letters fell primarily on the secretary, who had to carry on this work "after hours" at his home at Washington, Ind. He also devoted much time to the preparation of answers to the criticisms and objections of those who feared that the new association would encroach on the fields of existing organizations. In addition he undertook an analysis, briefing and tabulation of the comments elicited, so that the information could serve as a guide in drafting the constitution of the infant organization. Because of the indifference encountered in some quarters and open opposition in others, these months of preparation for the creation of the new engineering association were frought with many discouragements, but thanks to the persistence and courage applied by the small group of enthusiasts, the plans for the new organization came to fruition at a meeting held in Buffalo, N. Y., in March 1899, when the constitution was adopted, the membership roll was started, and the first slate of officers and directors was elected, including L. C. Fritch as the secretary.

Those who know the American Railway Engineering Association only as a going concern with a background of precedents for the minutest details of its workings, find it difficult to picture the situation that confronted the secretary who had to "start from zero." He had the support of an enthusiastic and sympathetic Board of Direction, whose personnel included men with association experience as members of the American Society of Civil Engineers. However, the plan that had been initiated in the new organization for member participation through the agency of working committees comprised such a radical departure from the activities of the latter that the older body offered little that could be used as a model. One of the first tasks that fell to the new secretary was the preparation of the first "Outline of Work," which he evolved in a form that differed but little from that used today. Furthermore, there were many problems that could not be anticipated, and when they confronted the Association's first administrative officer he had to deal with them on his own initiative.

At this late date it is impossible to determine the full extent of the influence that Louis Fritch exerted in molding the essential character of the Association's diverse activities, from the format of its publications to the manner of conducting its meetings, but there is no doubt that it was great. It is well established, however, that he was among the first to stress the importance of the Manual. He strong-urged the committees to keep in mind one objective—the formulation of recommended practices—and he overlooked no opportunity to point out the advantages to accrue to the railroads from the adoption of uniform practices in construction and maintenance of way.

Unlike his successors as secretary of the Association, L. C. Fritch never occupied that position on a full-time basis. Instead, as it became evident that the work of the secretary was more than could be handled in "spare time," arrangements were made by the Board of Direction to engage his brother, the late E. H. Fritch, in the capacity of assistant secretary, a position which the latter occupied until 1906, when he succeeded to the position of secretary. However, the intense interest that Louis Fritch had taken in the Association from the start continued unabated and in 1907 his valuable contributions to it were accorded further recognition by his election as a director, being advanced a year later to vice-president, and in March 1910 to the presidency. In 1926, pursuant to a petition presented to the Board of Direction, he was elected an Honorary Member.

Louis Charlton Fritch was born at Springfield, Ill., on August 11, 1869, the son of Joseph and Margaret (Mather) Fritch. At the age of 15 he obtained employment with the Ohio & Mississippi Railroad (now a part of the Baltimore & Ohio Railroad) as a roadmaster's clerk. While in this position he developed a keen interest in railway engi-

neering, and by the time he was 17 he had obtained a transfer to the office of the chief engineer, where he served as a helper in the maintenance of way engineering party. This new experience heightened his interest and brought the realization that advancement in this field demanded more formal education. Accordingly, he took up work at the University of Cincinnati, long recognized as a pioneer in the field of cooperative education, putting in substantially half a day in classes and the other half with the railroad. Young Fritch continued this arrangement for four years and obtained a diploma and with it the chance to end the double load, but instead of welcoming such a respite, he immediately started to study law and persisted until he had passed the bar examination.

In the meantime his railroad experience was broadened by expanding responsibilities. In October 1892, at the age of 23, he was advanced to engineer maintenance of way and served also as chief engineer in charge of the construction of a new line of the Ohio & Mississippi, known as the Cincinnati & Bedford. In November 1893, when the Ohio & Mississippi was absorbed by the Baltimore & Ohio Southwestern Railroad, he was appointed a division engineer of the latter, a position he retained until September 1899, when he was advanced to superintendent. In 1904, when I. G. Rawn, general superintendent of the Baltimore & Ohio Southwestern, resigned to become a vice president of the Illinois Central at Chicago, he offered Mr. Fritch a position as his assistant on special assignments, which the latter accepted, and two years later when the president of the railroad wanted an assistant on financial matters, special reports and various other problems, he appointed Mr. Fritch on Mr. Rawn's recommendation. In 1909, following several month's service as the representative of the Illinois Control in dealings with the City of Chicago bearing on the then current agitation for electrification of the railroads, he accepted appointment as the chief engineer of the Chicago Great Western Railway, which was then launching a program of extensive improvements and rehabilitation.

Although he had made great sacrifices to gain a formal education in railroad engineering, Mr. Fritch's interests in the field of railroad transportation soon transcended that special field. "I think every engineer should bear in mind," he said in the course of an interview, "the relation that his work bears to the main object of the railroad—transportation. It is only by keeping this in mind that he can hope to prepare himself for an operating position."

The influence of this attitude is reflected throughout his career from the time he left the Chicago Great Western in 1914 to become assistant to the president of the then Canadian Northern. In 1915, when the lines of railroad east of Port Arthur were opened to operation, he was made the general manager. Still later he became general manager of the Seaboard Air Line Railroad, and in October 1918 he became vice president of the Chicago, Rock Island & Pacific Railroad in charge of construction, maintenance, and capital expenditures. Subsequently, operation was also added to his responsibilities. He continued in the service of the Rock Island until his retirement in 1936.

For most of the years following his retirement, he made his home in Pasadena, Calif., where he was engaged occasionally in consulting work for some of the western railroads, and during World War II he served as federal coordinator of defense transportation for the Southern California Region. Returning to the Middle West in 1948 because of the failing health of Mrs. Fritch, he lived for a time in Wilmette, Ill., and later in Evanston.

He was married to Frances Myers Fritch at Jefferson, Ind., in 1904, who died after a long illness on December 7, 1952. Mr. Fritch was remarried on December 1, 1953, to Pearl Keefer Fritch, who survives him.

Mr. Fritch possessed to a high degree the mental skills and habits of personal efficiency and discipline so essential to success as an executive. In the words of a man

who was his secretary in his middle years, "I never met anyone who practiced greater concentration. He was not only fast at dictation, but he could dictate as many as 20 letters without referring to notes or correspondence. I have seen him interrupted in the middle of a sentence in a long letter and then, after an interval of several minutes, go on where he had left off without asking to have the sentence read. No one could go through a long report any faster and seem to gain a thorough knowledge of what was in it."

Such was the man who occupied an outstanding role in the beginning of the AREA. True, he shared the honors with two others—Augustus Torrey, who carried the banner from the inception of the organization until the first annual meeting, when John F. Wallace, vice-president of the Illinois Central, took over upon his election as the first president. Louis Fritch was much the junior of these two men both in years and position, yet who can say how long the founding of the Association might have been delayed but for the enthusiasm, persistence and energy applied by the young division engineer to the work he carried on by kerosene lamp night after night in a small town in Southern Indiana? The American Railway Enginering Association owes a deep debt of gratitude to Louis Charlton Fritch who is no longer with us.

W. S. Lacher, *Chairman,*
William Michel
G. J. Ray
D. J. Brumley
J. E. Armstrong
G. D. Brooke
C. H. Mottier
Committee on Memoir.

REPORT OF THE EXECUTIVE SECRETARY

March 1, 1956

To the Members:

If to have a successful Association year calls for advances on some fronts while holding the line on all other fronts, it can be said that the Association has just completed another successful year. Again, while adhering to its objective—the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways—much was accomplished through committee and associated research work; membership interest remained at a high level; the membership roll, despite heavy losses due to deaths and other causes, showed a slight increase; and the close of the year found the Association in a continuing healthy financial condition, in spite of several large and unusual expenditures.

Some of the important actions of the Association during the year, which in some cases are referred to in more detail later in this report, were changes in the Constitution to lower the annual dues of Junior Members from $7.50 to $5.00, and to change the title of the administrative officer of the Association from secretary to executive secretary; inauguration of a plan to include the portrait photographs of all officers and directors in the Annual Proceedings, and to present the photographs of all committee chairmen with the reports of their committees as published in the Bulletins and subsequently carried over into the Proceedings; the publication of 25,000 copies of an engineer recruitment brochure entitled, "The Railroad Field—A Challenge and Opportunity for Young Engineers", for free distribution to the engineering colleges and universities of the country; the adoption of a new masthead for the AREA News, effective with the January 1956 issue; the reaffirmation of the policy of the Association with respect to holding committee meetings at points most convenient to the majority of members in order to hold down traveling time and expense, except as meetings at other points are dictated by important considerations pertinent to the committee's work; and the development of plans, on an experimental basis, for an all-day Pre-Convention Motion Picture Theater and Coffee Bar on the Monday preceding the opening of the 1956 convention.

MEMBERSHIP

The membership in the Association as of February 1, 1956, stood at 3303, a net gain of 25, continuing further the unbroken record of membership increase each year since 1944. This net gain was 4 more than the net gain of 21 for the previous year, and 5 more than the net gain of 20 in 1953, but compares unfavorably with the average net gain of 57 for the 3 years prior to 1953. Furthermore, favorable as the general membership picture may appear on the surface, a breakdown of the membership figures for the past year indicates that the situation is not all that it should have been and bears watching, if not corrective action. For example, the number of new members (all grades) elected during the year ended February 1, 1956, was only 186, compared with 231 in 1954, and 203 in 1953, decreases of 45 and 17, respectively. Thus, if it had not been for 18 fewer resignations and 5 fewer deaths in 1955 compared with 1954, on the one hand, and 20 more reinstatements in 1955 than in the previous year, on the other hand, the net gain in membership during 1955 would have been converted into a loss in total membership over 1954.

But continuing a policy that membership in the Association is something to be sought rather than "sold", no concerted membership effort was made during the year.

Committees of the Board of Direction 1955–1956

Outline of Work

Ray McBrian (chairman), B. R. Meyers, G. W. Miller, C. H. Sandberg, W. H. Giles.

Personnel of Committees

H. R. Peterson (chairman), Ray McBrian, G. W. Miller, C. B. Porter, R. H. Beeder.

Publications

C. H. Sandberg (chairman), Wm. J. Hedley, H. B. Christianson, E. J. Brown, F. R. Woolford.

Manual

Wm. J. Hedley (chairman), C. G. Grove, W. H. Giles, C. J. Code.

Membership

E. S. Birkenwald (chairman), C. G. Grove, H. B. Christianson, H. R. Peterson, R. H. Beeder.

Finance

B. R. Meyers (chairman), G. E. Robinson, E. J. Brown.

Special AREA Services

G. E. Robinson (chairman), E. S. Birkenwald, C. B. Porter, C. J. Code, F. R. Woolford.

However, noting not infrequently in the personnel columns of railway trade publications, and elsewhere, the names of engineering and maintenance officers who have never affiliated themselves with the Association, the Board of Direction authorized the secretary's office to extend to these men an invitation to apply for membership. Beginning this practice in August, only a limited number of invitations were sent out up to the first of February 1956, and only a very few availed themselves of the invitation. However, as the result of this gesture, it can never be said by these men that the Association did not extend its hand, and that they were not members because "no one had ever invited them to join."

Another disturbing factor in the membership activity of the Association during the past year is the further net loss that occurred in the number of Junior Members, from 187 as of February 1, 1955, to 163 as of February 1, 1956. Thirty-eight new Junior Members were taken into the Association during the year ended February 1, 1956, compared with 41 in 1954 and 39 during the preceding year. However, the transfer of 5 Juniors to the grade of Member and the dropping out of membership of 57 others brought about the net loss of 24, to the February 1, 1956, total of 163, representing a continuing loss from the 187 as of the same date in 1955, 220 the previous year, and the record number of 261 Juniors in the year ended February 1, 1953.

It is to be expected that a considerable number of the young technical graduates who enter railway service and become Junior Members will drop out of railroad service each year and give up their Association membership, but that does not explain com-

pletely why so relatively few Junior Members, upon reaching the age requirement for Members or the age limit of 30 for Juniors, transfer to the grade of Member, nor does it explain why a larger number of the new technical graduates employed by the railroads each year do not become affiliated with the Association promptly as Junior Members. Regarding the latter, surely something further should be done in the years ahead to stimulate early interest among these young men in Association membership.

The specific changes in the status of membership in the Association during the past year are detailed in the following tabulations:

MEMBERSHIP

(February 1, 1955, to February 1, 1956)

Members on the rolls February 1, 1955	3278
New members	186
Reinstatements	34
	3498
Deceased	41
Resigned	38
Dropped	92
Net Loss Juniors (transferred 5; dropped 57; additions 38)	24
	195
Net gain	25
Membership February 1, 1956	3303

MEMBERSHIP CLASSIFICATION AS OF FEBRUARY 1

	1950	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*
Life	339	355	361	375	401	436	465
Member	2276	2243	2284	2312	2366	2381	2414
Associate	280	274	288	289	270	274	261
Junior	158	220	257	261	220	187	163
Totals	3053	3092	3190	3237	3257	3278	3303

During the year there was a total of 41 deaths among the membership, as is recorded in the roster of deceased members at the end of this report. Through these deaths, the ranks of Charter Members of the Association were further reduced to a total of two, in the passing, on July 23, 1955, of Louis Charlton Fritch, who was not only a Charter Member, but an Honorary Member, first secretary of the Association, and its eighth president, and the death on April 12, 1955, of Theodore Lincoln Condron, who, after many active years of Association work, became a Life Member in 1936. A memoir to Mr. Fritch appeared in Bulletin 524 for September–October 1955, beginning on page 313, and a memoir to Mr. Condron appeared in Bulletin 526 for December 1955, on page 530. Both of these memoirs will be reprinted in the 1956 Proceedings of the Association. The two surviving charter members are E. C. Macy, and William Michel.

Among the other members who died during the past year were I. H. Schram, retired chief engineer of the Erie, who was a director of the Association from 1949 to 1951, who was active over many years on the Committees on Track and Rail, being chairman of the former committee in the years 1944–1946, and who became a Life Member in 1951;

G. W. Harris, retired chief engineer of the Santa Fe System, who was a director of the Association from 1930–1932, and a member of the Rail committee from 1936 to 1947; H. S. Jacoby, professor emeritus of bridge engineering at Cornell University, who was chairman of Committee 7—Wood Bridges and Trestles, from 1907 to 1911; C. T. Jackson, retired chief engineer of the Milwaukee Road, who had been active on a number of committees over the years, and on Committee 5—Track, from 1937 to 1950, of which he was elected a Member Emeritus in 1953; and W. H. Wallace, retired assistant engineer on the Rock Island who many older members may recall was very active on the Convention Arrangements Committee of the Association back in its early years.

ACTIVITIES OF COMMITTEES

Membership on Committees

Again in 1955, membership on the Association's 23 standing and special committees reached another all-time high, with the prospect of a still further increase under the two new rules adopted by the Board in 1954 to spread further the advantages of committee membership among members and the railroads, while at the same time bring to committees increased knowledge and experience. One of the new rules adopted increased from 60 to 70 the number of members permitted on a committee, while the other revised the former rule respecting retired members on committees to the effect that they no longer count against the total of 70 permitted on committees, or against the quota permitted on a committee from any railroad or other organization.

On February 1, 1956, 1132 members (including 53 Members Emeritus) were serving on committees, occupying a total of 1253 places on these committees, since a number of members serve on 2 committees. This compares with 1078 members who occupied 1213 places on committees on the same date in 1955, and with 1035 members who served in 1165 places on committees 2 years ago.

Again during the past year practically all committees carried "Guest" members on their rosters—members awaiting definite assignment to the committees with the roster changes last fall, but who were allowed to participate unofficially in committee work. In addition, an increasing number of "Visitors" were welcomed to meetings, including retired members, Junior Members, interested outsiders, and members of the Association generally, who for one reason or another could not be assigned to committees, but who wished to participate in specific meetings or the inspection trips in connection therewith.

Work of Committees

The work of committees during 1955 again followed the more normal pattern of preparing progress and information reports, of revising and refining Manual material and the Trackwork Plans, and of developing new Manual material and Track Plans. Among the many outstanding features of this work were the completion and printing of 25,000 copies of the engineer recruitment brochure developed by Committee 24—Cooperative Relations with Universities, and the extensive revision, by Committee 5—Track, of the Portfolio of Trackwork Plans, both of which are referred to further under "Publications". The accompanying table reflects the classification of material contained in committee reports, as presented at annual meetings, for the past eight years.

Classification of Material in Committee Reports

(Figures shown indicate the number of Manual documents affected or new reports)

	1949	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*
Revisions of Manual with or without reapproval	37	24	20	19	257	14	24	18
Reapproval of Manual material without revisions	7	5	5	2	243	1	0	0
New Manual material	4	6	5	6	12	9	10	11
New Manual material—tentative	2	4	2	8	6	7	6	4
Information	35	49	57	43	49	59	53	46
Reports on research work	19	18	23	15	18	23	26	19
Reports on service tests	7	7	1	10	13	10	10	9
Statistical data	4	2	3	9	5	4	3	4
Analytical studies	14	7	2	2	5	3	2	5
Bibliographies	2	3	3	2	2	2	3	3
Brief reports of progress	20	13	8	16	11	17	16	15
	151	138	129	132	621	149	153	134

Committee Meetings

Primarily in the interest of efficiency and economy in the conduct of committee work, only 66 full committee meetings were held during the year ended March 1, 1956, which is the smallest number of such meetings held in any year since 1950. On the other hand, a large number of committees desirably held their first, or reorganization, meeting prior to the March 1956 convention in order to get an early start on the coming year's work, and one committee—24—Cooperative Relations with Universities, for the first time held two committee meetings under a newly adopted policy to hold two meetings each year—one at a railroad headquarters, and the other on the campus of one of its professorial members. In addition, many committee meetings again included inspection trips of one kind or another in the interest of committee work.

The total of 66 full committee meetings held during the past year, which includes a number of luncheon meetings held during the 1955 annual meeting, compares with 67 meetings held during the year ended March 1, 1955, 76 meetings held in 1953, 79 meetings held in 1952 (a year in which a number of extra meetings were held in conjunction with the Centennial of Engineering), and 69 meetings held in 1951. During 1955 one committee held 5 meetings, 4 committees held 4 meetings, 9 committees held 3 meetings, and 9 committees held 2 meetings.

Of the 66 meetings, 39 were held in Chicago, 4 were held in Detroit, Mich., 3 were held in St. Louis, Mo., 2 each were held in Cincinnati, Ohio, Madison, Wis., and Urbana, Ill., and 14 were held in as many different cities.

The large number of meetings held in Chicago and other central locations reflects the long-standing policy of the Association, reaffirmed by the Board of Direction during 1955, that committee meetings or subcommittee meetings may be held wherever to the best advantage of committees, but, other things being equal, they should be held at points most convenient to the majority of members in order to hold down traveling time and expense.

With the beginning of the Calendar Year 1955 there was considerable concern both among the officers of the Association and committees as to the possible effect on the location of committee meetings, and attendance thereat, of the restrictions on passes for business purposes (including travel to committee meetings) then being put into effect

by a few eastern railroads. This concern proved to be largely unfounded as the adoption of these restrictions did not spread to other railroads, and their only effect, if any, was the tendency to avoid scheduling meetings at points reached only via lines where pass privileges are restricted.

Key Position of Chairman Recognized

To a greater extent than ever before, the Board of Direction and the secretary's office endeavored to cooperate with committees in the handling of their work and in bringing about a clear understanding of their assignments and of the rules governing committee procedure. Once again, following a practice of recent years, with the exception of 1954, all committee chairmen met in Chicago on April 26 with members of the Board and of the secretary's office to review all matters affecting committee work and procedures, and to discuss as well possibilities for improving the convention activities of the Association. This meeting of all committee chairmen differed from the plan followed in 1954, when only the newly appointed chairmen in that year were brought together, with the thought that it was not necessary to call an all-chairmen meeting each year, and that considerable travel time could be saved chairmen by not doing so. As further evidence of this thinking, the Board of Direction, at its meeting on March 17, adopted a new policy of holding all-chairmen meetings only each second year, but to include in the invitations to these meetings the vice chairmen of those committees which will change chairmanship the following year. No disadvantage is contemplated in this new policy, especially in view of the comprehensive Information and Rules for the Guidance of Committees, and Style Standards, presented in the Outline of Work Pamphlet each year, and the recent addition to the pamphlet of a detailed table of contents, which makes it possible for chairmen to locate readily reference to any matter which may be in doubt.

To recognize and honor committee chairmen for their interest and effort in behalf of the Association, the practice was continued of presenting each new committee chairman, as he assumed the chairmanship at the annual meeting in March, with an attractive gavel, with a polished brass band bearing his name, the committee number, and the years of his term of office. Likewise, the chairmen were the guests of the Association at a Second Speakers' Table at the Annual Luncheon of the Association at the convention in March, and for the first time, at that convention, each chairman was given an attractive blue lapel ribbon bearing the words "AREA Chairman", in gold, which he was expected to wear as a badge of honor and identity. And, not satisfied in this regard, the Board, early in 1956, was giving consideration to still additional ways in which it might suitably recognize and honor committee chairmen, some of which will, no doubt, be in evidence at the 1956 convention.

PUBLICATIONS

The 7 Bulletins ending with the February 1956 issue contain 1116 pages of text matter and illustrations, exclusive of advertising, in addition to 11 inserts of one kind or another. This compares with 1255 pages in the 7 Bulletins ending with the February 1955 issue, and with the 1138 pages for the 7 Bulletins ending with the February 1954 issue.

The committee reports published for presentation at the March 1956 annual meeting occupied 572 pages in Bulletins 525 to 528, incl., which compares with 664 devoted to

committee reports in comparable Bulletins of the previous year. This reduction in the number of Bulletin pages devoted to reports is accounted for by the some fewer total number of reports made during the year on committee assignments, but also reflects the admonition of the Board of Direction to committees to present their reports as concisely as possible.

To the number of Bulletin pages devoted to committee reports during the past year should be added the 312 pages of reports on research projects sponsored by AREA committees, or groups in which AREA committees are interested, which appeared in Bulletins 523 and 524 for June–July 1955, and September–October 1955, respectively. These 312 pages reporting on research projects compare with 322 pages devoted to the same type of material in the previous year.

Engineer Recruitment Brochure

The outstanding special publication effort of the Association during 1955 was the publication, with the assistance of the Public Relations Department of the Association of American Railroads, of an engineer recruitment brochure, designed to assist the railroads in attracting into their service young technically trained men from the graduating classes of the engineering schools of the country. This brochure, which was based on a 1955 report of Committee 24—Cooperative Relations with Universities, prepared with the cooperation of the various divisions and sections of the AAR, is a 2-color, 28-page, profusely illustrated booklet, 8½ in by 11 in, with an eye-catching, futuristic, wrap-around cover.

Based on estimates furnished by the accredited engineering colleges and universities of the country as to their requirements for the brochure for the next three years, and upon estimates of other valuable outlets for the booklet, 25,000 copies were printed during September, 15,000 for distribution by the AREA, and 10,000 for distribution by the Public Relations Department of the AAR.

All copies to the colleges and universities, in the number requested, as well as to libraries and high school student counselors making request, were sent out free, while railroads desiring copies in multiple to assist them in their own engineer recruitment efforts were charged the actual production cost of 21 cents each.

Indicative of the demand for the brochure, which continues, is the fact that by December 31, 1955, 5140 copies had been sent out from the secretary's office—4848 to colleges and universities, 129 to high school counselors, and 163 to other interested individuals. In addition, as of the same date, as is noted under the heading "Sale of Publications", 2103 copies had been sold to railroads.

This large demand for the brochure, plus the many letters of appreciation and commendation from the colleges and universities, testifies adequately to its favorable acceptance for the purpose for which it was designed and to the wisdom of the Board of Direction in authorizing its publication. On the other hand, whereas it was anticipated that the initial supply of 15,000 copies for the AREA would be adequate to meet requirements for a period of 3 years, it now appears that the supply will be completely exhausted well before that time.

Supplements to Manual and Portfolio of Trackwork Plans

The Annual Supplement to the Manual issued in 1955, incorporating all of the recommendations of committees affecting Manual material adopted at the 1955 annual meeting, included a total of 104 sheets, 27 of which involved changes in the Tables of

Contents of the various chapters. As a whole, this Supplement called for the removal of 78 existing sheets from the Manual, leaving a net gain of 26 sheets in the Manual as revised. The Manual Supplement in 1955 compares with the 98-page Supplement issued in 1954.

The Annual Supplement to the Portfolio of Trackwork Plans issued in 1955 represented outstanding effort on the part of Committee 5—Track, in a comprehensive review of all of the trackwork plans, and embraced practically a complete revision of the entire Portfolio. This Supplement contained 89 new or revised plans, a new Table of Contents, and 2 Appendix sheets covering revisions in the AREA Specifications for Special Trackwork, as authorized by action at the annual meeting of the Association in March 1955.

Concurrent with the publication of the 1955 Supplement, the secretary's office reprinted a sufficient number of the remaining sheets of the Portfolio to replenish its supply of completely up-to-date Portfolios. This volume now consists of 118 plans, 8 pages of special trackwork specifications, 5 pages of definitions of terms relating to switches, frogs, guard rails, crossings and turnouts, and a contents sheet.

Sale of Publications

In the Calendar Year 1955, the Association continued widespread distribution of its publications over and above those copies going to its own large membership. This distribution, up about 500 over the previous year, included approximately 32,900 copies, 25,260 of which were sold from the secretary's office to, among others, the American railroads, colleges and universities, students, government agencies, engineers in industry generally, and railroad men in foreign countries. The remaining 7640 copies included the more than 5000 copies of the engineer recruitment brochure sent out free to engineering colleges and universities from the secretary's office, and approximately 2500 reprints of research reports sent out free by the AAR research staff.

Following is a tabulation of the publication sales made in 1955:

Sales of Association Publications—1955

Specifications (Bridge)	1,286
Manual chapters	517
Manual specifications and partial chapters	1,244
Manual specifications, large orders (more than 100)	5,600
Bulletins	1,164
Bulletin reprints	198
Special reprints in large orders (100 or more)	10,700
Proceedings	256
Consolidated Proceedings indexes	48
Revisions to Manual	554
Manuals (complete) and separate fillers	200
Revisions to Portfolio of Trackwork Plans	799
Complete Portfolios of Trackwork Plans	51
Individual track plans	435
Instructions for Mixing and Placing Concrete	13
Federal Valuation of Railroads	5
Achievement of Grade Crossing Protection	33
J. A. Given booklets	54
Engineer recruitment brochure	2,103
	25,260

Large as was the distribution of publications in 1955, it again reflects the continued refusal of the Association to fill many foreign orders received which did not have the sanction of the Office of International Trade at Washington, D. C.

FINANCES

The Report of the Treasurer, Financial Statement, General Balance Sheet, and Statement of Cash Receipts and Disbursements for the Calendar Year 1955, all of which are presented herein, indicate that the Association is in a sound financial condition. Receipts during the year exceeded Disbursements by $6254.03. A comparison of the Receipts and Disbursements for the past two years is presented below:

	1954	*1955*
Receipts	$85,748.99	$80,177.21
Disbursements	68,003.03	73,923.18
	$17,745.96	$ 6,254.03

Reviewing the situation briefly, Receipts in 1955 were some $5570 under those of 1954. This decrease was more than accounted for by the more normal Manual receipts in 1955—some $12,000 under the excessively high Manual receipts of 1954, which resulted from the heavy demand for the newly reprinted Manual which became available for sale in November 1953.

Offsetting the decrease in receipts was an increase of some $4500 in 1955 Track Plan receipts over those for 1954. The abnormally high Track Plan receipts were due entirely to sales of the 1955 Supplement to the Portfolio, which, as indicated earlier in this report, included 89 plans, or approximately 75 percent of the entire Portfolio.

Disbursements for 1954 and 1955 do not represent a fair comparison for several reasons—principally with regard to expenditures for Trackwork Plans, Manual and the engineer recruitment brochure. Total Disbursements for 1955 were $5880 higher than in 1954. The Financial Statement indicates that $3391 were expended for the engineer recruitment brochure in 1955, with no expenditure for this item in 1954. Trackwork Plan expenditures for 1955 were $8463, compared to only $1130 in 1954. Total expenditures for these two items alone were $10,724 greater in 1955 than in 1954. Also, the cost of the Annual Meeting in 1955 was some $400 higher than in 1954.

Conversely, only $2470 were expended for the Manual in 1955, compared with $5984 in 1954, or $3514 less. The higher Manual expenditure in 1954 was due to the purchase in that year of a supply of Manual binders, and the payment early in the year of the balance due on the complete Manual reprinting, which amounted to $936. Also, due to a combination of favorable conditions, which resulted in printshop economies, expenditures for the items of Proceedings and Miscellaneous Stationery and Printing were $2100 under like expenditures in 1954.

Thus, whereas expenditures during 1955 for Trackwork Plans, recruitment brochure and annual meeting were $11,124 higher than in 1954, expenditures for Manual, Proceedings, and Miscellaneous Stationary and Printing were $5614 lower in 1955—a differential of $5510. This differential, compared with the higher expenditures of $5880 in 1955, indicates that, even with a slight general increase in the cost of doing business in 1955 over 1954, all other disbursements items were in very close proximity to like expenditures in 1954.

Thus, with Receipts over Disbursements of $6254.03 in 1955, the General Balance Sheet shows liquid assets for 1955 of Investments $141,200.14 and Cash $126.75, and comparable items for 1954 of $131,241.39 and $3831.47. Total assets of the Association for 1955 were $150,991.31 (with total liquid assets of $141,326.89), and for 1954 $145,194.08 (with total liquid assets of $135,072.86.)

The 1955 assets of the Association carry, as inventory, on a conservative cash basis, $3566.40 for Manual fillers, which will eventually be converted into cash—again indicating that the 1953 Manual reprinting was a sound investment, and that despite the gratis distribution of new fillers to member holders of the previous edition, has paid for itself. Also included in the assets, as inventory on a conservative cash basis, is $2126 for Trackwork Plans. In view of the large receipts for these plans in 1955, it is a fact that if only the inventory value of these plans is realized, which is expected, the 1955 Trackwork Plan edition will pay for itself—a condition that has not prevailed previously.

Comparison of Receipts and Disbursements for a 20-Year Period

	Receipts	*Disbursements*	*Net Gain*
1936	$28,643.00	$34,662.00	$6,019.00*
1937	36,523.00	32,200.00	4,323.00
1938	28,422.00	23,394.00	5,028.00
1939	28,189.00	23,847.00	4,342.00
1940	28,272.00	26,451.00	1,821.00
1941	32,433.00	29,384.00	3,049.00
1942	31,500.00	26,692.00	4,808.00
1943	28,736.00	23,809.00	4,927.00
1944	30,492.00	26,534.00	3,958.00
1945	32,305.00	29,305.00	3,000.00
1946	28,836.00	34,583.00	5,747.00*
1947	46,993.00	46,989.00	4.00
1948	57,741.00	53,062.00	4,679.00
1949	62,081.00	57,075.00	5,005.00
1950	59,752.00	51,795.00	7,957.00
1951	69,045.00	62,369.00	6,676.00
1952	77,514.00	76,964.00**	550.00
1953	73,033.07	82,067.86**	9,034.79*
1954	85,748.99	68,003.03**	17,745.96
1955	80,177.21	73,923.18	6,254.03

* Deficit.

** Manual revision and reprinting 1952, $4908.09; 1953, $20,572.58; 1954, $936.54.

RESEARCH WORK

The research activities of the Association, sponsored by its committees and carried out by the research staff of the Engineering Division, AAR, and the facilities of several colleges and research organizations, continued at a productive level in 1955 and accomplished much. Again, however, due to conditions within the industry, not as much was actually undertaken and accomplished as had been contemplated or hoped for originally by the AREA committees involved; in fact, only $351,653 were authorized and spent for Engineering Division research activities in 1955, which is practically the same amount as was spent in 1954—a year of declining railroad revenues.

Again in 1956, AREA research activities, as financed by the AAR, will not be all that was tentatively hoped for by committees, due in large measure to the supplemental AAR appropriation of an additional $470,000 for the construction in 1956 of a new Engineering Laboratory at the AAR Research Center in Chicago, to augment the Administration Building and Mechanical Laboratory there. Thus, several new projects of committees, already deferred for one or two years, will necessarily be held over for another year, and several new projects which committees had hoped to get underway in 1956 cannot be undertaken.

Whereas the Engineering Division research budget was submitted in the amount of $438,815, this was necessarily reduced to $365,050, which is only slightly higher than the amount spent in both 1954 and 1955. The projects to be continued or initiated in 1956, and the amount appropriated for each, compared with 1955 and 1954, is shown in the second accompanying table:

TOTAL ALLOTMENTS FOR RESEARCH WORK, ENGINEERING DIVISION, AAR, 1939–1956

1939	$ 77,650	1948	$291,840
1940	69,250	1949	372,457
1941	95,150	1950	294,045
1942	87,932	1951	354,770
1943	98,445	1952	381,400
1944	109,050	1953	364,100
1945	138,110	1954 (as modified)	351,307
1946	159,510	1955	351,653
1947	234,428	1956	365,050

ENGINEERING DIVISION ALLOTMENTS FOR RESEARCH 1954–1956

	1954 Budget	*1955 Budget*	*1956 Budget*
Committee on Rail			
Transverse Fissure Investigation	$ 5,590	$ 5,600	$ 5,600
Shelly Spots Investigation	9,400	9,000	9,850
Rail Failure Statistics	8,860	8,950	8,950
Service Tests of Joint Bars	2,825	2,825	3,225
Rolling-Load Tests of Joint Bars	12,225	11,725	11,725
Rail Design Investigation	12,300	13,000	2,500
Rail End Batter	4,000	4,500	11,000
Tests with 78-ft. Fail	3,500	3,500	5,000
Total	$ 58,700	$ 59,100	$ 57,850
Committee on Track			
Tie Plates, Stresses	$ 5,300	$ 5,300	$ 4,400
Bolt Tension and Joint Lubrication	3,920	3,500	4,500
Corrosion from Brine Drippings	11,250	11,000	13,000
Manganese Frog Design	4,500	3,400	4,900
Tests of Rail Anchorage	4,500	400	.....
Tie Plate Fastenings	13,600	13,900	17,600
Welding Carbon Steel Frogs and Switches	7,100	6,600	6,400
*Laying Rail Tight with Frozen Joints	.....	.....	5,100
Total	$ 50,170	$ 44,100	$ 55,900
Relation Between Track and Equipment			
Jack-Knifing of Diesel Locomotives	.....	$ 10,000	$ 4,000
Relation Wheel Load to Wheel Diameter	$ 5,225	5,200	5,000
*Ride Comfort—New Type Trains	.....	.....	5,000
Clearance Requirements	8,000	.....	4,000
Relation of Wheel Pressures to Truck Curvature	2,225	.....	.....
Total	$ 15,450	$ 15,200	$ 18,000

* New Projects in 1956.

Committee on Roadway and Ballast	*1954 Budget*	*1955 Budget*	*1956 Budget*
Roadbed Stabilization	$ 24,000	$ 24,000	$ 24,000
Ballast Tests	8,000	8,000	8,000
Vegetation Control by Chemicals	13,000	13,000	12,300
Total	$ 45,000	$ 45,000	$ 44,300
Committee on Ties			
Wear and Splitting of Ties	$ 10,000	$ 10,000	$ 10,000
Total	$ 10,000	$ 10,000	$ 10,000
Structural Projects			
Bridge Impact Investigation	$ 72,787	$ 70,140	$ 70,000
Stress in Bridge Frames	2,750	10,000	10,500
Riveted and Bolted Structural Joints	8,000	8,000	8,000
Column Research Council	1,000	1,000	1,000
Steel Structures Painting Council	8,000	8,000	8,000
Timber Stringer Tests	5,500	5,500	1,500
Fire Retardant Coatings—Performance	5,260	5,260	9,900
Concrete Deterioration	9,200	9,200	10,500
Reinforced Concrete Research Council	4,000	4,000	4,000
Strength of Timber Bolted Joints	2,800	2,800	3,000
Tests of Membrane Waterproofing Material	6,172	6,200	6,500
Tests of Bituminous Materials	9,208	9,000	6,100
Wind Loads on Buildings	1,000	1,000	1,000
Total	$135,677	$140,100	$140,000
Committee on Wood Preservation			
*Termite Control Investigation	.....	.....	$ 1,000
Total	.....	.....	$ 1,000
Administration			
Research Office	$ 36,310	$ 38,153	$ 38,000
Total	$ 36,310	$ 38,153	$ 38,000
Grand Total	$351,307	$351,653	$365,050

* New project in 1956.

What of 1956?

Thus, another Association year has passed into history. That it was another good and fruitful year should be cause for satisfaction and gratitude. As for 1956, it, too, can be a good year—a still better year—with the continued loyal support of the membership and a constant endeavor to forge ahead with its work and to overcome any indicated weaknesses and shortcomings of the past.

Respectfully submitted,

Neal D. Howard,
Executive Secretary.

Deceased Members

H. C. Archibald

Retired Assistant Chief Engineer, Boston & Maine Railroad, Melrose, Mass.

A. A. Bareuther

Representative, R. W. Hunt Company, Chicago, Ill.

D. P. Beach

Retired Assistant Chief Engineer Maintenance of Way, Pennsylvania Railroad, Wayne, Pa.

R. J. Bieth

Retired Assistant Division Engineer, New York, New Haven & Hartford Railroad, Hartford, Conn.

Theodore Bloecher

Retired Assistant Office Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

E. R. Bryant

Technical Service Director, Universal Atlas Cement Company, New York, N. Y.

J. F. Canning

President, Southwestern Petroleum Company, Inc., Ft. Worth, Tex.

T. L. Condron

629 North Oak Park Avenue, Oak Park, Ill.

C. H. Crawford

President, Schori Process Corporation, Chesapeake, Lawrence County, Ohio

L. W. Dawson

Assistant Engineer, New York Central System, Jersey Shore, Pa.

E. M. Durham, Jr.

900 South Price Road, Clayton, Mo.

P. Fiorenza

Supervisor of Work Equipment, Texas & Pacific Railway, Dallas, Tex.

C. H. Fox

Retired Special Engineer, Canadian Pacific Railway, Vancouver, B. C.

O. H. Frick

Retired General Manager, Chicago Union Station Company, Wauwatosa, Wis.

L. C. Fritch

Retired Vice President, Chicago, Rock Island & Pacific Railroad, Evanston, Ill.

G. W. Harris

Retired Chief Engineer System, Atchison, Topeka & Santa Fe Railway, Beverley Hills, Calif.

J. W. Hopkins

Engineer of Track, Bessemer & Lake Erie Railroad, Greenville, Pa.

C. T. Jackson

Retired Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Columbia, Mo.

C. Jacoby

Valuation Engineer, Southern Railway System, Washington, D. C.

H. S. Jacoby

Professor Emeritus of Bridge Engineering, Cornell University, Kirkersville, Ohio

B. E. Jacocks

Assistant Division Engineer, Louisville & Nashville Railroad, Knoxville, Tenn.

J. P. Kivlen

Superintendent, Northampton & Bath Railroad. Northampton, Pa.

A. E. Korsell

Retired Engineer of Grade Crossings, Chicago, Rock Island & Pacific Railroad, Mankato, Minn.

J. C. Korte

Draftsman, Pennsylvania Railroad, Cincinnati, Ohio

C. E. Loos

Assistant Metallurgical Engineer, United States Steel Company, Pittsburgh, Pa.

L. L. Lowe

Assistant Superintendent, Missouri Pacific Railroad, Wynne, Ark.

H. W. McLeod

Retired Principal Assistant Engineer, Canadian Pacific Railway, Vancouver, B. C.

A. H. Meyers

Assistant Engineer—Valuation, Texas & Pacific Railway, Dallas, Tex.

J. M. Minturn, Jr.

Division Engineer, Pennsylvania Railroad, Cleveland, Ohio

W. N. Myers

Division Engineer, Pennsylvania Railroad, Pittsburgh, Pa.

P. H. Peters

Assistant Signal Engineer, Missouri Pacific Lines, Houston, Tex.

H. S. Rimmington

Bridge Engineer, Canadian National Railways, Winnipeg, Man.

H. B. Rutherford

Division Engineer, New York Central System, Watertown, N. Y.

I. H. Schram

Retired Chief Engineer, Erie Railroad, University Heights, Ohio

H. C. Schultz

Real Estate Agent, Grand Trunk Western Railroad, Detroit, Mich.

J. M. Short

General Water Service Inspector, Texas & Pacific Railway, Dellas, Tex.

P. E. Thian

Retired Consulting Engineer, Northern Pacific Railway, St. Paul, Minn.

O. A. C. Thorsen

Chief Engineer, New York, Susquehanna & Western Railroad, Paterson, N. J.

G. C. Tuthill

Retired Bridge Engineer, Michigan Central Railroad, Highland Park, Mich.

A. E. Walker

Construction Engineer, Atchison, Topeka & Santa Fe Railway—Coast Lines, Los Angeles, Calif.

W. A. Wallace

Retired Assistant Engineer, Chicago, Rock Island & Pacific Railroad, Fairbury, Nebr.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDED DECEMBER 31, 1955

Balance on hand January 1, 1955		$135,097.86

RECEIPTS

Membership Account		
Entrance Fees	$ 1,860.00	
Dues	42,545.38	$44,405.38
Sale of Publications		
Proceedings	1,930.35	
Bulletins	1,517.95	
Manuals	6,769.31	
Specifications	2,810.84	
Track Plans	5,996.29	
Research Reports	6,808.59	$25,833.33
Advertising		
Publications		$ 5,929.12
Interest Account		
Interest on Investments		$ 3,369.08
Miscellaneous		$ 640.30
Total		$80,177.21

DISBURSEMENTS

Salaries	$21,196.69	
Proceedings	13,011.95	
Bulletins	11,408.10	
Stationery and printing	2,600.40	
Rent, light, etc.	1,140.00	
Supplies	390.98	
Postage	1,930.31	
Audit	400.00	
Pensions	1,500.00	
Social security and unemployment taxes	429.70	
Manual	2,470.10	
Track plans	8,463.70	
Committee and officers expense	349.07	
Annual meeting expenses	2,166.82	
News letter	2,435.69	
Miscellaneous	596.94	
Brochure	3,391.48	
Loss from sale of Bonds	41.25	
Total		$73,923.18
Excess of Receipts over Disbursements		6,254.03
Balance on hand December 31, 1955		$141,351.89

REPORT OF THE TREASURER

To the Members:		
Balance on hand January 1, 1955		$135,097.86
Receipts during 1955	$ 80,177.21	
Paid out on audited vouchers	73,881.93	
Excess of Receipts over Disbursements	$ 6,295.28	
Loss from sale of bonds	41.25	6,254.03
Balance on hand December 31, 1955		$141,351.89
Consisting of bonds at cost	$141,200.14	
Cash in Northern Trust Company Bank	126.75	
Petty cash	25.00	$141,351.89

We have made an examination of the accounts of the American Railway Engineering Association for the year ending December 31, 1955, and find them to be in accordance with the foregoing statement.

C. A. Bick,
P. D. Mitchell,
Auditors.

GENERAL BALANCE SHEET

Assets	*1955*	*1954*
Due from members	$ 31.00	$ 21.00
Due from sale of publications	42.15	133.95
Due from sale of advertising	876.80	658.40
Due from prepaid postage	41.52	19.23
Furniture and fixtures	1,145.50	1,220.30
Inventory of publications (estimated)	500.00	500.00
Inventory of Manuals	3,566.40	5,406.40
Inventory of track plans	2,126.00	1,681.00
Inventory of binders, index and chapters	17.10	20.73
Inventory of paper stock	850.00	142.80
Investments (cost)	141,200.14	131,241.39
Interest accrued on investments	442.95	292.41
Cash in Northern Trust Company Bank	126.75	3,831.47
Petty cash	25.00	25.00
Total	$150,991.31	$145,194.08
Liabilities		
Members dues paid in advance	$ 338.30	$ 476.80
Surplus	150,653.01	144,717.28
Total	$150,991.31	$145,194.08

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS YEAR 1955

Cash in Bank January 1, 1955		$ 3,831.47
Receipts		
From members, sale of publications, interest, etc.	$ 80,177.21	
Sale of bonds	4,000.00	84.177.21
		$ 88,008.68
Disbursements		
Audited Vouchers	$ 73,881.93	
Government bonds purchased	14,000.00	$ 87,881.93
Cash in Bank, December 31, 1955		$ 126.75

American Railway Engineering Association

CONSTITUTION

Revised to December 2, 1955

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than 25 years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereto, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

B. Member

A Member shall be:

(a) An engineer or officer in the service of a railway corporation that is a common carrier, who has had not less than five years' experience in the location, construction, operation or maintenance of railways.

(b) A dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency who, in the discharge of his regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of his regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer, engaged in private practice, or an engineer in his employ or in the employ of a consulting engineering organization, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member or an Associate who has paid dues for 35 years, or who has been retired under a recognized retirement plan and has paid dues for not less than 25 years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. Associate

An Associate shall be:

(a) An engineer of a railway which is essentially an adjunct of an industry, or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to cooperate with Members in the object of this Association, but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than 21 years of age and shall be an engineering employee of a railway corporation who has had not less than three years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this classification in the Association shall terminate at the end of the calendar year in which he becomes 30 years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership, any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members, and Life Members who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these Members shall be requested by the Executive Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom he is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested by the Executive Secretary of the Association to certify to a personal knowledge of the applicant, with an opinion of the applicant's qualifications for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with the required information, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible, and the admission of the applicant shall be canvassed by ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

An applicant for any class of membership in this Association shall declare his willingness to abide by the Constitution of the Association in his application for membership.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, the person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of $10 shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be required for Junior Membership, except that a Junior Member, in transferring to another class of membership, shall pay the entrance fee prescribed for other classes of Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $15.

(b) The annual dues for each Junior Member shall be $5.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction.

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Executive Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he will no longer receive the publications of the Association. If the dues are not paid by December 31, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice Presidents, twelve Directors, an Executive Secretary and a Treasurer.

(b) The President, the Vice Presidents and the Directors, together with the two latest living Past Presidents continuing to be Members, shall constitute the Board of Direction, in which the government of the Association shall be vested; they shall act as the trustees and have the custody of all property belonging to the Association. The President, the Vice Presidents and the Directors shall be Members.

(c) The Executive Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice Presidents two years and of the Directors three years. The term of each shall begin at the close of the annual convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position at the pleasure of the Board of Direction.

3. Officers Elected Annully

(a) There shall be elected at each annual convention a President, one Vice President and four Directors.

(b) The candidates for President and for Vice President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

6. Vacation of Office

(a) In the event of the death of an elected officer, or his resignation from office, or if he should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past President who is a member of the committee shall be the chairman of the committee. In the absence of the senior Past President from a meeting of the committee the Past President next in seniority present shall act as chairman.

2. Method of Nominating

(a) Prior to December 1 of each year the chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The chairman of the Nominating Committee shall send the names of the nominees to the President and Executive Secretary not later than December 15 of the same year, and the Executive Secretary shall report the names of these nominees to the members of the Association not later than January 1 following.

(c) At any time between January 1 and February 1 any ten or more Members may send to the Executive Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, his name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each annual convention, the Executive Secretary shall issue a ballot to each voting Member of record who has paid his dues to or beyond December 31 of the previous year, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his record of membership and activities in this Association.

4. Substitution of Names

Members may remove names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Executive Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and cast another, at any time before the polls close.

(c) Ballots received in unendorsed envelopes, or from persons not qualified to vote, shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at 12 o'clock noon on the second day of the annual convention, and the ballots shall be counted by tellers appointed by the presiding officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the annual convention shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

2. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

3. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Executive Secretary and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

4. Executive Secretary

The Executive Secretary, under the direction of the President and Board of Direction shall be the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and record the proceedings thereof. The Executive Secretary shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the Treasurer therefor. He shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. He shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee and approved by the Board of Direction, with notification to the Treasurer of such investments. The Executive Secretary shall conduct the correspondence of the Association, make an annual report to the Association, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution.

(b) The Board of Direction shall meet within thirty days after each annual convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the annual convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction, and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publications
Outline of Work of Committees
Personnel of Committees
Membership
Manual

Other special committees may be appointed by the President at his discretion.

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of funds and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision over the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall review and pass upon the recommendations of standing and special committees for subjects to be investigated, considered and reported on by these committees during the ensuing year, and shall report thereon to the Board of Direction for its approval.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall review and pass upon applications of members for appointment to standing and special committees. It also shall appoint the chairman and vice chairman of such committees and make a report thereon to the Board of Direction for its approval.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee, with the assistance of the Publications Committee, shall have general supervision over the Manual.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The convention shall open on the second Tuesday in the month of March, or on the third Tuesday if the month of March has five Tuesdays, excepting that some other opening day in March may be designated by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Executive Secretary shall notify all members of the Association of the time and place of the annual convention at least 30 days in advance thereof.

(c) The order of business at the annual convention of the Association shall be:

Reading of the minutes of the last meeting
Address of the President
Reports of the Executive Secretary and the Treasurer
Reports of committees
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to Members and to those others invited by the presiding officer to speak.

2. Special Meetings

Special meetings of the Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members, and shall be acted upon in the following manner:

The amendment shall be presented to the Executive Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes, the matter shall be submitted to the Association by letter ballot.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association.

Information and Rules for the Guidance of Committees

The following information and rules for the guidance of committees are designed to obtain the maximum benefits from the efforts of the members who make up the personnel of such committees. They are designed to effect a continuity of effort in committee work throughout the entire year, under a plan whereby the personnel of the committees and their respective outlines of work are set up and made public on or before the beginning of the calendar year, thus enabling the work to be continued without interruption, although the new personnel and subject assignments do not become officially effective until the beginning of the "Association Year," which starts with the close of the annual meeting.

The rules also take into account the fact that the publication of the committee reports must be spread out over a period of four months (November through February), to facilitate printing and to give members of the Association a reasonable length of time in which to study such reports in advance of the annual meeting.

SUBJECT ASSIGNMENTS

Reassigned Annually

The outline of work of each committee shall be reviewed annually. To this end, each committee shall review suggestions for new subjects submitted by the members thereof, or by others, and such suggestions as receive the approval of the committee shall be submitted by the committee chairman to the executive secretary of the Association not later than October 1, together with the committee's recommendations covering the withdrawal or continuation of current assignments.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Outline of Work, which shall have the responsibility of authorizing the subject assignments to the various committees. Deviation from assignments thus authorized may be made during the course of the year only upon the authority of the Board Committee on Outline of Work.

COMMITTEE PERSONNEL

Reorganized Annually

The personnel of each committee shall be reorganized annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committee, who do not render service by correspondence, or who do not return letter ballots will be dropped. To this end the chairman of the committee shall submit to the executive secretary of the Association not later than October 1 the names of members whom he recommends be dropped because of delinquencies in service to the committee, as well as a list of the names of members of the Association whom he recommends for appointment to the committee.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Personnel, which has the duty of appointing the committee personnel.

No additions to the personnel of committees will be made during the year following the official closing of committee rosters, October 1, except as provided for in the rules applying to "Guests."

Members who desire appointment to a committee should make application through the chairman or the executive secretary on the prescribed form.

(Revised November 4, 1955).

Chairmen, Vice Chairmen and Subcommittee Chairmen

† Chairmen and vice chairmen must hold the grade of Member in the Association, and be in active railroad service. Subcommittee chairmen may be anyone holding the grade of Member, except that any Associate currently acting as a subcommittee chairman may continue to hold such office until succeeded by a Member.

The terms of chairmen and vice chairmen shall be three years in each position. Chairmen completing their three-year term shall recommend to the Board Committee on Personnel nominees for the chairmanship and vice chairmanship, with assurance of acceptance from such nominees if appointed by the Board Committee. The term of office of subcommittee chairmen may be more than three years.

Committee Secretary

Any chairman may appoint a secretary with duties usually encompassed by such office.

Size of Committees*

The total membership of any committee shall be limited to 70. In determining the membership of a committee. railroads having no more than 50 Association members may have not more than 2 members on any committee; railroads having 51 to 100 members may have not more than 3 members on any committee; railroads having more than 100 members may have not more than 4 members on any committee.

No college, university or other institution of learning shall have more than 2 members on any committee, and no manufacturer or supply company or other organization shall have more than 1 Associate member on any committee.

† In applying the rules set forth in the two preceding paragraphs, Junior Members shall be counted, but retired members shall not be counted.

Retired Members

Members who have retired from active service under normal retirement procedure, regardless of whether they undertake other employment, may serve on committees a maximum of three years following retirement, but without voting rights. Their presence on the committee roster shall not be counted in the application of the rules affecting the total number of members permitted on committees, the number of associates permitted on a committee, or the rules having bearing upon the number of members on committees permitted from any railroad, supply company, or other organization. Following termination of their service on committees, retired members may continue to attend committee meetings as "visitors" subject to the approval of the committee chairman involved.

Associate Members*

No company will be permitted to have more than one Associate member of any committee, and company representation shall not necessarily be continuing. However, in the event that a railroad member on a committee becomes associated with a manufacturer or supply company after retirement from railroad service on pension, and thus automatically becomes an Associate member, he shall not be deprived of membership on the committee during the period of three years following his retirement from railroad service.

---

* In applying any of the rules under the headings: Size of Committees and Associate Members see paragraph under heading "Retired Members," and third last paragraph under heading "Member Emer'tus."

† Revised or new.

† The membership of Associates on a committee shall be limited to 10 percent of the total membership of the committee. Committees with Associates in excess of 10 percent of their total membership are not required to reduce the number of Associates immediately for the purpose of complying with this rule, but no Associates may be added as long as the proportion of Associates exceeds 10 percent, except as may be occasioned by the exception provided in the preceding paragraph or the exceptions set forth under "Retired Members" and "Member Emeritus."

Member Emeritus

This class of committee membership was established in 1953 in order to permit recognition of long-sustained meritorious service of committee members to committees, following their retirement and the termination of their regular membership on committees.

To be eligible for this honor, a member must be in good standing in the Association as a Member, Honorary Member, Associate, or Life Member, and must have:

(a) Retired under normal retirement procedure from active service in the company with which he has been connected.

(b) Served on the committee at least 10 years. (Executive secretary's office can furnish service record on any retired committee member.)

(c) Resigned from the committee or have been removed from the committee under the rule that retired members can remain on a committee only three years following the date of their retirement.

(d) Rendered outstanding service to the committee over a period of years.

(e) Been proposed by at least five committee members in writing and voted the honor by a two-thirds affirmative letter ballot of all members of the committee, including Associates (the letter ballots to be returnable to the executive secretary's office within 60 days).

The number of such members permitted on any committee will be limited to five.

Furthermore, his election as Member Emeritus must be affirmed by the Board Committee on Personnel through the executive secretary's office.

Having been elected as Member Emeritus, the member's name will continue to appear on the roster of the committee, and he will have all the rights and privileges of members except that of voting (i.e., can serve on subcommittees, should he desire, in order that the committee might benefit from his knowledge and experience). Likewise, his name will continue to be shown in the printed roster of the committee appearing in the Bulletins of the Association, and in the Outline of Work Pamphlet, in each case suitably designated as Member Emeritus. However, the names of Members Emeritus will not be designated by an "E" or otherwise in the alphabetical listing, railroad listing, Honorary Member listing, or Life Member listing in the March Bulletin.

Members Emeritus will not be counted in the application of the rules affecting the total number of members permitted on committees, the number of associates permitted on a committee, the rules having bearing upon the number of members on committees permitted from any railroad, supply company, or other organization, or the number of years that a retired member may serve on a committee. Any Emeritus title will terminate with the death of the recipient, or in the event of the termination of his membership in the Association for other reasons.

Nothing in these rules will prevent extending the honor of Member Emeritus to a retired committee member who may have taken up, or who subsequently takes up, other employment following his official retirement.

† Revised or new.

Tangible evidence of this honor will be given to those so named in the form of a pocket card, similar in form to a railroad pass, signed and sent out by the committee chairmen.

"Guests" and "Visitors"

The previously stated rule under Committee Personnel Reorganized Annually, that "no additions to the personnel of committees will be made during the year following the official closing of committee rosters, October 1, except as provided for under the rules applying to "Guests," does not preclude the attendance at committee meetings of other members of the Association, as "visitors," with the approval of committee chairmen.

If there are vacancies on a committee roster after the official closing of committee rosters on October 1, (i.e., less than 70), or if vacancies occur during the following year, or are definitely in prospect at the end of that year, Association members (including Junior members), with the approval of committee chairmen and the Board Committee on Personnel, can be appointed as "guests" of that committee. As such, they may attend committee meetings and participate in the committee's activities, unofficially, looking to becoming regularly assigned members at the beginning of the next Association year (March).

"Guests" must always be designated as such on the rosters maintained by the committees and the secretary's office, but their names will not appear in published committee or subcommittee reports. Creation of this class of committee affiliation is not intended to increase the size of any committee beyond the 70 maximum set by the Board, but rather to make it possible to add to "short" rosters between official roster changes.

Furthermore, one need not be either a "regular member" or a "guest" of a committee to attend its meetings from time to time. With the approval of the committee chairman, who must be consulted as regards any specific meeting, any AREA member (including Junior members) may sit in on the meeting as a "visitor," listen to all deliberations and participate in discussions.

Service on More Than One Committee

No member of the Association shall serve on more than one committee, except that a member may serve on two committees if one or both of the committees are among the following: Committee 3—Ties; Committee 7—Wood Bridges and Trestles; Committee 17—Wood Preservation; Committee 20—Contract Forms; Committee 24—Cooperative Relations with Universities; Committee 25—Waterways and Harbors; Committee 28—Clearances; Committee 29—Waterproofing; Committee 30—Impact and Bridge Stresses; and the Special Committee on Continuous Welded Rail.

COMMITTEE ORGANIZATION AND PROCEDURE

Organizing the Committees

The new outline of work and personnel of committees shall become effective with the close of the annual meeting in March. However, the pamphlet containing this information is issued not later than January 1 in order that committees may be reorganized immediately after January 1 for the new year's work, if reorganization has not already been effected. Usually this information will be available to the chairmen in tentative form at least 30 days in advance of publication.

It is the duty of the committee chairman to notify new members promptly of their appointment and to notify old members of their reappointment or release. It is also his duty to reorganize the subcommittees without delay. However, in the Association year in which his term as chairman expires, he should call on his successor for advice and assistance in this regard.

Subcommittees

In general, the committees are organized to conduct their work by the appointment of one subcommittee for each subject assignment. If deemed advisable, any subject may be subdivided into several parts and a separate subcommittee assigned to each part. Committees may find it of advantage to create a subcommittee on personnel as well as a subcommittee on new subjects.

Organization Charts

The chairman shall furnish the executive secretary of the Association two copies of the organization chart (schedule of subcommittee assignments and personnel) of his committee, and shall advise him currently of any subsequent revisions thereof. This chart may be in the form regularly used by committees, but should not be in the form of a blueprint, on which it is difficult to make corrections. White prints are acceptable. These charts should be in the hands of the executive secretary by February 1, and should be prepared with the greatest care to insure the accuracy of initials and names.

The names of "guest" members on committees, if any, (not "visitors") should appear on the charts, but should be clearly designated as such. These names may be arranged either alphabetically among the members or grouped at the bottom of the chart as desired by the various committees. Names of "visitors" should not appear on or be subsequently added to these charts. Charts should also list separately the names of all collaborators with other AREA committees and with other organizations.

Handbook for Committee Chairmen

For the assistance and guidance of committee chairmen in the conduct of their committee work, the Association has published a small mimeographed "Handbook for Committee Chairmen", which contains the following material:

Procedures that Can Be Adopted by Committee Chairmen to Stimulate the Most Effective Committee Work.

Procedures Designed to Expedite the Conduct of Committee Meetings, Stimulate Greater Interest in Them, and Produce the Most Effective Results.

Report of a Well Conducted Committee Meeting.

Copies of this handbook are available to committee chairmen from the executive secretary's office.

Voting in Committees

† Voting in committees and subcommittees on all Association matters, except as may be of a social nature, or on ballots for Member Emeritus of the committee, shall be the prerogative of active Members only; not retired Members, Associates, or Juniors.

† Revised or new.

COMMITTEE MEETINGS

Location and Number

Most committees find it possible to conduct their work effectively with a maximum of three meetings each year. While these meetings can be held at any time to fit in best with the committees' work, the trend in recent years has been for committees to hold first (organization) meeting each year in January or February in order to get an early start on their new year's work, and not to wait till after the annual convention in March. Subcommittee meetings can likewise be held whenever desired, either in conjunction with or independent of full committee meetings, but are usually held the day prior to general committee meetings at the point of the general meetings.

† Committee meetings or subcommittee meetings should be held at points most convenient to the majority of members in order to hold down traveling time and expense, except that meetings may be held elsewhere to permit inspections important to the work of the committee or subcommittee. Meetings should be held where no charge is made for meeting rooms, since the Association has no funds to defray meeting room costs.

Notices and Minutes

The committee chairman shall send copies of all notices of committee meetings to the executive secretary of the Association as early as possible for publication in the AREA News. Copies of all minutes of meetings must also be filed with the executive secretary.

COLLABORATION

Between AREA Committees and with AAR Committees

Subjects, the nature of which clearly indicates the possibility of overlapping interest of two or more AREA committees, or the committees of other groups with which the Association has agreed to collaborate, carry an appended clause reading: "collaborating with ....." It is the duty of the chairmen of the subcommittees having an assignment carrying this instruction to take the initiative in effecting such collaboration;—first, by requesting the appointment of representatives of the other interested group or groups, should such be mutually decided as desirable, and second, by submitting copies of AREA reports to them for comment. Regardless of whether the assignment specifically mentions collaboration, committees shall be on the alert to obtain the advice and assistance of other AREA committees or interested groups in dealing with any subject that imposes any questions of possible overlapping interest or responsibility.

A committee undertaking revision of its Manual chapter should request collaboration of any committee that participated in the original development and adoption of the material under revision. The executive secretary of the Association will provide information concerning such previous collaboration.

With Other Organizations

Many AREA committees appoint representatives to serve as collaborators on committees of the American Standards Association, the American Society for Testing Materials, the American Concrete Institute, or other outside organizations, these representatives acting either directly for the AREA committees or in behalf of the Association of American Railroads which may hold membership in the organizations involved. In

† Revised or new.

all such cases, representation in these other organizations, either initially or otherwise, is handled through the AREA executive secretary's office. Thus AREA committee nominations for representatives on these outside committees, or for changes in representatives, are made through the executive secretary's office, which transmits the nominations to the organizations, secures their acceptance, notifies those interested, and makes official record thereof.

Beyond this point the representatives carry on their collaboration independent of the executive secretary's office, but each AREA committee should keep on its organization chart a record of all of the organizations with which it collaborates, and the names of its collaborators.

WORK OF THE COMMITTEES

Objectives

The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

Planning the Work

In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

Committees are privileged to obtain data or information in any proper way. If desired, the executive secretary will issue circulars of inquiry, or questionnaires, prepared by committees, which should be brief and concise. The questions contained in such circulars should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. The circulars should specify to whom answers are to be sent, and should be furnished in duplicate so that a copy can be retained by persons replying.

Research

† Requests for appropriations for the conduct of research work should be sent to the director of engineering research, AAR, with copy to the executive secretary of the AREA, with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigation. A request for funds to continue or complete an investigation shall include also a statement of the results obtained to date. All requests for research appropriations, with supporting data, must be in the hands of the director of engineering research by July 1.

† Revised or new.

Maintaining Manual Up to Date

Each committee shall critically review the material in its chapter of the Manual at such intervals as to insure that it is kept up to date. It shall resubmit all Manual material for revision or reapproval at intervals of not more than 10 years. This rule, however, is not intended to encourage the reapproval of documents only at 10-year intervals. On the contrary, and especially since each document in the Manual, beginning with its reprinting in 1953, carries a reapproval line under its heading, committees are urged to recommend the reapproval of documents each time that revisions (major or minor) are proposed, using some such wording as "Reapprove with the following revisions". If such reapproval is not requested specifically when revisions are recommended, the document will continue to carry its previous adoption or reapproval line.

However, since two or more sheets must be issued in a Supplement every time a document is reapproved without revisions, to correct the document date and the contents page or pages, it is recommended that, in the interest of avoiding unnecessary printing costs, documents which do not require revisions should not be offered for reapproval at intervals of less than 8 or 10 years.

Group Revisions in Specific Years

While it is a healthy situation for committees to be constantly on the alert to improve their respective documents in the Manual, and while some revisions in Manual material will be of a character that will require that they be made at the earliest possible date, many changes will be of an editorial or less important character and will not demand that they be made immediately.

Accordingly, in the interest of economy, committees should, insofar as possible, group their revisions in any specific document, looking to submitting them as a whole at intervals of two or three years or more, rather than separately year after year—thus avoiding the necessity for reissuing the same Manual pages in successive years, to the greatest extent possible.

NATURE AND PREPARATION OF REPORTS

Form of Report

It is important that committee reports be prepared in accordance with the Style Standards for committee reports, as detailed on following pages in this pamphlet.

Reports on All Assignments Not Necessary

Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on assignments with respect to which pertinent information has been developed.

Nature of Report

Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant

their presentation as information prior to the submission of the recommendations. In some cases, it may be advisable to submit as information material in the form of recommended practice with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the material for adoption at a later date.

When the work has been completed on any assignment, the committee should request the Board Committee on Outline of Work that the assignment be discontinued.

A report should be designated a "final report" only when the committee has completed its study of an assignment and asks that the subject be discontinued, and does not contemplate restudy of the subject in the immediate or foreseeable future; otherwise, the report should be designated a "progress report".

Presentation of Material in Reports

Many progress or final reports, whether based on research or other investigation, best lend themselves to written presentation in orderly sequence or chronological arrangement, ending with any conclusions or recommendations which may have been arrived at. However, in most cases, and especially in the case of long reports, to conserve the time of members who may or may not be interested in the details of the study involved, it is recommended that reports be introduced with a brief highlight summary statement of the background, purpose and extent of the study, as may be desirable, and including a synopsis of any conclusions, recommendations or other results—this latter material to supplement a more detailed presentation elsewhere in the reports.

Reports of information, supplementing previous reports of progress, may include a brief review of material previously presented, but should avoid extended repetition of such material.

Use of Trade Names

Committee reports which are based upon physical research or field tests carried out by or through the research staff of the Engineering Division, AAR, may use trade names or manufacturers' names in referring to products, machines, devices or processes under test. No other committee reports, however, shall contain the trade names of products, machines, devices or processes, nor the names of manufacturers, unless in each instance approval is secured from the Board Committee on Publications prior to the publication of the reports. To seek such approval, a committee must submit five copies of the report in question to the executive secretary's office, for transmission to the members of the Board Committee, six weeks prior to the scheduled filing date of the report. If time does not permit a ruling upon the request of the committee prior to the publication date of the report in question, the report of the committee must either be altered to eliminate the trade names or terms involved, or be withdrawn, at the discretion of the committee which prepared it.

Nature of Manual Material*

The material adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required,

* Same applies to Portfolio of Trackwork Plans.

either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Printing of Manual Material*

Material offered for adoption and publication in the Manual, except as noted herein, should be submitted in full, regardless of its publication in previous years, unless the material in question appeared in substantially identical form not more than one year before being submitted for adoption. Such material shall appear in the report of the committee that is published not less than 30 days before the annual meeting at which it is to be presented. Recommended revisions of Manual material, if extensive, shall include only the proposed material, which shall be printed in full in the report of the committee. Manual material recommended for reapproval, or for deletion, shall be presented by title and page reference only. Likewise, plans, specifications or other documents of other organizations recommended for adoption by the AREA shall be presented by title and serial designation only, e.g., current ASTM specifications, designation D 17.

When entirely new material is offered for inclusion in the Manual, the committee sponsoring it should state specifically in its report the exact location the material is to have in the Manual.

Letter Ballot Required of Committee*

† Any action recommended by a committee with respect to the adoption, revision, reapproval or withdrawal of Manual material must have received prior endorsement by the committee in the form of an affirmative vote of two-thirds of the voting membership of the committee, such vote to be taken by letter ballot. Associates, Junior members, Members Emeritus, and retired members on a committee are not entitled to vote. Thus, it is imperative that committee members promptly consider and vote on all letter ballots, seeking the advice of other committee members or specifically qualified officers on their own roads if in doubt as to whether to vote for or against a proposal.

PUBLICATION OF REPORTS

Dates for Filing Reports

To insure the orderly publication of the reports in accordance with a predetermined schedule, it is necessary that chairmen file complete reports with the executive secretary of the Association on or before the dates specified in the Outline of Work pamphlet. The manuscript of the report must be furnished in duplicate, preferably double spaced. Piecemeal filing of reports by subcommittee chairmen is permissible only under special arrangement (in writing) with the executive secretary of the Association.

* Same applies to Portfolio of Trackwork Plans.
† Revised or new.

PRESENTATION OF REPORTS AT ANNUAL MEETINGS

Presentation of Reports

Since both the degree of effectiveness with which a report is received by those assembled in annual convention, and the accuracy with which it can be reported in the Proceedings, depend upon the clarity with which the oral presentation is made to the meeting, it is desirable that committee members write out and read their presentations, and that they speak directly and distinctly into the microphone at the rostrum, raising or lowering the microphone as may be necessary to that end. In the event that written presentations are read, a copy of such presentations should be given to the executive secretary or to the convention reporter before the speaker leaves the rostrum.

Reports offered as information should be presented by title or by a brief highlight outline of the contents. Material submitted for adoption and publication in the Manual* may be presented by reading the title and subtitles, but the presiding officer may, upon request, authorize the reading of specific portions of the material being offered.

Oral Discussions

Comments on or criticisms of any report may be offered from the floor. When necessary to insure accuracy, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

Written Discussions

Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Action on Reports

No formal action is to be taken by the convention on material submitted as information, whether in the form of a progress or final report.

Action on material submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.

(b) Affirmative action on the amendment of a part or parts of the material presented, followed by adoption as a whole as amended.

(c) Adoption of a part, complete in itself, and referring the remainder back to the committee for further consideration.

(d) Recommittal with or without instructions.

Note.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

* Same applies to Portfolio of Trackwork Plans.

MISCELLANEOUS

Memoirs

The Association has developed a complete set of rules with respect to memoirs in committee reports or elsewhere in its publications, covering the scope, preparation and presentation of such memoirs. Copy of these rules, as well as the Association service record of any deceased member, can be secured from the executive secretary's office.

Letter Ballot of Membership

When and as required between annual meetings, recommendations for the adoption, deletion, revision or reapproval of Manual material shall be submitted to letter ballot of the Members of the Association under the following limitations:

(a) That the letter ballot shall be taken only after the Board of Direction has recognized the necessity for such emergency action, and

(b) That the propositions submitted by the committee shall have the approval of a special committee of the Board of Direction appointed by the President for that purpose, both as to the substance of the material offered and also as to the circumstances attending the consideration of the material by the committee.

The Board of Direction, acting under the provisions of paragraphs 6 (a) and 11 of Article VII of the AREA constitution, has the authority to amend, delete or revise Manual material at any time, subject to later confirmation or rejection by the membership, submission to the membership to be effected either by means of a letter ballot immediately following such Board action, or by a motion presented at the annual meeting.

Review by Association of American Railroads*

All material adopted for publication in the Manual and all recommendations for the revision or withdrawal of Manual material shall be referred to the vice president, Operations and Maintenance Department, Association of American Railroads, for review, before distribution is made thereof to holders or purchasers of the Manual, or parts thereof.

Publication of Annual Supplement*

Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those sheets that have been withdrawn by action of the Association.

Publication of Abstracts by Technical Journals

The following rules will govern the releasing of material for publication in technical journals:

Committee reports to be presented at an annual meeting will not be released for publication until after presentation to the annual meeting. Special articles, contributed by members and others, on which no action by the Association is necessary, will be released for publication in technical journals only after issuance in a Bulletin; provided, application therefor is made in writing and proper credit is given the Association, authors or committees presenting such material.

* Same applies to Portfolio of Trackwork Plans.

INDEX OF PROCEEDINGS, VOL. 57, 1956

A

Accounting, ICC classifications, revisions and interpretations, 641, 926

Agreement form, insurance provisions recommended for, 350, 921

Agreement form, subsurface rights to mine under railway property, 350, 921

Agreement form, turnpike or toll road crossing railway track and property, 355, 922

Archibald, H. C., memoir, 1044

Atchison, Topeka and Santa Fe, manganese crossing test, 687, 1066

B

Baker, L. O., AAR weed control project, 662, 1079

Ballast, research project on, 661, 1078

Baltimore and Ohio Chicago Terminal, manganese crossing test, 687, 1066

Banana handling at water terminals, rail facilities for, 370, 930

Batteries, storage, for work equipment, 496, 1039

Bibliography, concrete, admixtures for, 539, 997

—records, and accounts (See Records and Accounts)

—waterways and harbors, 377, 949

Bigos, Joseph, chemical cleaning and painting of railroad bridges, 1

Brentlinger, P. D., panel discussion, ties, 1059

Bridges, chemical cleaning and painting of, by Joseph Bigos, 1

—design loading, economics of various, 558, 1000

—flood damage to by hurricane Diane, by W. R. Wilson, 1009

—girder and truss spans, dynamic shear in, 434, 993

—girder spans, tests of on CMStP&P, 134, 993

—impact (see Impact)

—lateral bracing, stress in, 435, 993

—movable, specifications, revisions, 555, 998

—ore, structural members, fatigue failures of, 175

—ore, structural members, fatigue failures, prevention of, 207

—painting and chemical cleaning of, by Joseph Bigos, 1

—painting and preparation of steel surfaces, 556, 999

—paints, substitutes for on steel, 557, 1000

—prevention of damage to from brine drippings, 696, 1066

—steel, erection specifications, revisions, 555, 998

—steel, specifications, revisions, 554, 998

—steel truss spans with open and ballasted decks, 435, 993

—stress distribution in frames, 556, 999

—timber stringer, stresses and impacts in, 435, 994

Brine drippings, prevention of damage from to track structures, 698, 1066

—protection from, bridge paint test, 557, 999

Budgetary procedures in railway engineering, 599, 924

Buildings, report and discussion, 381, 1023

Burt, C. S., panel discussion, ties, 1059

C

Cal Sag committee report in opposition to Cal Sag project, summary, by A. L. Sams, 949

Car repair tracks and facilities location and design, relation to classification tracks, 374, 931

Cathodic protection of pipe lines and steel storage tanks, 337, 964

Chesapeake and Ohio, rail, service test, 833, 1092

Chicago and North Western, relocation of tracks, O'Hare field, Chicago, 649, 1080

—service tests of 78-ft rail, 859, 1093

Chicago, Milwaukee, St. Paul & Pacific, girder and truss spans, dynamic shear in, 434, 993

—lateral bracing, stresses in, 435, 993

—relocation of tracks at O'Hare field, Chicago, 649, 1080
tests of girder spans, 434, 993

—tests of steel girder spans, 15

—welded frogs, tests, 768, 1073

Chicago, Rock Island & Pacific, service test records of treated ties, 447, 1029

Chromated zinc arsenate, specification, 465, 1021

Cincinnati, New Orleans & Texas Pacific, tie plate service test, 700, 1067

Classification yards (see Yards)

Clearances, report and discussion, 547, 991

—allowances for vertical and horizontal movement of equipment, 549, 992

—requirements of the various states, 548, 992

College and high school students, booklet to stimulate interest in engineering career, 577, 970

College students, cooperative system of education, 574, 970

—stimulate greater interest in science of transportation, 572, 969

—summer employment of, 574, 970

Collister, L. C., panel discussion, ties, 1059

Concrete, bibliography on admixtures for, 539, 997

—box culverts, reinforced, specifications for design and construction, 531, 996

—bridge slabs, reinforced, tests of full size, 434, 993

—deterioration, waterproofing coatings to prevent, 439, 1018

Constitution, AREA, 1121

Construction contract form, cost-plus, revision, 348, 921

—reports and property records, 620, 925

Continuous Welded Rail, report and discussion, 775, 1054

Contract Forms, report and discussion, 347, 920

—(see also Agreement forms)

—cost-plus construction, 348, 921

Cooperative engineering education fiftieth anniversary of, by Prof. O. W. Eshbach, 574, 970

Cooperative Relations with Universities, report and discussion, 571, 969

Cornell, W. E., address, better human relations as a key to improving maintenance of way work, 1051

Courts and regulatory bodies, decisions affecting valuation accounting and records, 638, 925

Cramer, R. E., address, investigation of failures in control-cooled rail, 1088

—joint investigation of fissures in rails, progress report, 787, 1088

—report on joint metallurgical societies meeting in Europe, 299

—shelly rail studies, progress reports, 850, 1092

Cross tie research, cooperative, between NLMA and AAR, address by G. M. Magee, 1057

Crossings, highway-railway grade, highway improvement projects, effect on railway properties, 333, 959

—metal grating type, merits and economics of, 326, 953

—recommended protection where one-way traffic crosses one or more tracks, 331, 959

—stop sign for use of crossing watchmen, 329, 954

Crossings, pipe line, under railway tracks, 645, 1077

—railway, service tests of manganese castings, 687, 1066

—service tests of solid and manganese inserts supported by steel T-beams and longitudinal timbers, 689, 1066

—trackwork plans (see trackwork plans)

Culverts, box, reinforced concrete, design and specifications, 531, 996

Curves, elevation and speeds on, revisions, 764, 1072

D

Davis, R. P., panel discussion, college graduates, railroad employment versus other industry employment, 971

Denver and Rio Grande Western, rail, service test, 831, 1092

Departure yards (See yards)

Diesel locomotive shop facilities, 382, 1024

Diesel locomotives, detection and disposal of radioactive materials in filters of, 344, 968

—oil and water servicing facilities, 342, 966

—water conditioning for cooling system, 337, 964

Drafting practices, 595, 923

Drew, L. P., panel discussion, ties, 1059

Duluth, Missabe and Iron Range, rail, service test, 833, 1092

Duncan, H. R., panel discussion, ties, 1059

E

Easement applications, highway, streets, roadway, outline guide for, 327, 953

Echols, G. H., panel discussion, college graduates, railroad employment versus other industry employment, 971

Eckel, E. B., address, landslides and their significance to the engineer, 1081

Economics of Railway Labor, report and discussion, 397, 1044

Economics of Railway Location and Operation, report and discussion, 313, 944

Edgar Thomson Steel Works, field investigation of ore bridge, 189

Electronic weighing of freight cars in motion, address, by V. C. Kennedy, 932

Electro-osmosis, roadbed stabilization by, 658, 1080
Engine wheel burns, rail failures prevention, repair by welding, 883, 1094
Eshbach, Prof. O. W., address, fiftieth anniversary of cooperative engineering education, 474, 970
—panel discussion, college graduates, railroad employment versus other industry employment, 971

F

Fire retardant coatings, including paints, for wood bridges and trestles, 566, 977
Fox, E. N., greetings from Signal Section, 900
Freas, Alan D., address, development of working stresses for glued laminated lumber, 979
Fritch, Louis Charlton, memoir, 1101
Gary Steel Works, field investigation of ore bridge, 179

G

Geyer, C. J., address, highlights of work performed by committee on track, 1073
Girder spans, steel, tests of, 15
Gordon, K. H., greetings from Electrical Section, 900
Graphical symbols, revisions, 582, 923
Great Northern, service test on heat-treated rail, 837, 1092
Grove, C. G., panel discussion, college graduates, railroad employment versus other industry employment, 971

H

Hale, H. H., adress, proposed highway legislation, 960
Hanrahan, Frank J., address, use of structural glued laminated lumber by railroads, 986
Harris, G. W., memoir, 1087
Highway improvement projects, effect on railway properties, 333, 959
—legislation, proposed, address, by H. H. Hale, 960
—trailers on flat cars, economics of service, 314, 945
Highways, report and discussion, 325, 952
—limited access, in vicinity of or crossing railways, problems related to location and construction, 331, 958
Hillman, F. W., statement and report of treasurer, 899, 1120
Holle, Maj. Gen. Chas. G., address, engineering for mobility, 914
Hopkins, J. W., memoir, 684
Howard, N. D., executive secretary's statement and report, 898, 1105
Human relations, better, as a key to improving maintenance of way work, address by W. E. Cornell, 1051

I

ICC accounting classifications, changes in, 641, 926
Illinois Central, rail joint lubrication service test, 735, 1070
—service test records of treated ties, 454, 1020
—tests of hold-down fastenings for tieplates, 707, 1068
—tie plate service test, 706, 1067
Impact and Bridge Stresses, report and discussion, 433, 993
—bridge, tests on CMStP&P, 15
—concrete bridge slab, full-size, tests of, 434, 993
Insurance provisions recommended for various agreement forms, 350, 921
Iron and Steel Structures, report and discussion, 553, 998

J

Jacoby, Cornelius, memoir, 580
Jensen, R. S., rolling load tests of joint bars, 817, 1092
Johnston, Wayne A., address, the ever-new challenge of railway engineering, 1002
Joint bars, rolling load tests, 817, 1092
—service tests of, 817, 1092
—specifications, revisions, 784, 1088

K

Kennedy, Verne C., address, electronic weighing of freight cars in motion, 932
Kistler, L. W., panel discussion, ties, 1059

L

Labor, costs, maintenance of way work, analysis of operations to reduce, 398, 1044
—economy of renewing ties by use of proper equipment and organization, 423, 1046
—economy of trucks versus motor cars to transport, 424, 1048
—means of conserving, 570, 978
Laminated lumber, glued, working stresses for, address by, A. D. Freas, 979

—structural, glued, use of by railroads, address by F. J. Hanrahan, 986

Landslides, their significance to the engineer, address by E. B. Eckel, 1081

Laughnan, Don F., address, painting frame buildings, 1025

Lease, form of, covering subsurface rights to mine under railway property, 350, 921

Loading and unloading facilities, highway semi-trailers on railroad cars, 373, 930

Loadings, design, bridge, economics of various, 558, 1000

Loomis, E. E., AAR weed control projects, 662, 1079

Louisville and Nashville, tests of hold-down fastenings for tie-plates, 707, 1068

Lubrication, tests of to prevent rail joint freezing, and to prevent corrosion, 735, 1070

Luncheon, annual, 1001

M

Magee, G. M., address, cooperative research on Ties by the NLMA and the AAR, 1057

—rail failure statistics, 1091

Maintenance forces, size of for tie renewals, using on and off-track tampers, 430, 1050

Maintenance of way work, analysis of operation on Southern, 398, 1044

Maintenance of Way Work Equipment, report and discussion, 473, 1037

Marine organisms, prevention of damage by, 457, 1021

Marmaduke, Harvey C., address, building people, 906

Masonry, report and discussion, 529, 996

May, R. G., address, fair treatment for all, 903

Metallurgical Societies, joint, European meeting of, 299

Meyers, A. H., memoir, 581

N

Norfolk and Western, rail, service tests, 834, 1092

O

Office and drafting practice aids, 595, 923

Oil and water servicing facilities, diesel locomotives, 342, 966

Ore bridges, failures in structural members of, 175

Ore bridges, fatigue failures, recommendations for prevention of, 207

O'Rourke, G. M., president's address, 893

P

Painting frame buildings, address by Don F. Laughnan, 1025

Painting and preparation of steel surfaces, 556, 999

Paints, substitutes for on steel bridges, 557, 1000

Panel discussion, how can railroads attract and hold an adequate number of qualified engineering graduates in competition with other industries?, by C. G. Grove, G. H. Echols, D. W. Tilman, R. P. Davis, O. W. Eshbach, 971

Panel discussion on ties, by L. C. Collister, L. P. Drew, C. S. Burt, P. D. Brentlinger, H. R. Duncan, L. W. Kistler, 1059

Passenger terminals, revision, 364, 928

Peck, R. B., relocation of railroad embankment, O'Hare field, Chicago, 649, 1080

—roadbed stabilization by electro-osmosis, 658, 1080

Pennsylvania, bridge paint test, 557, 999

—rail, service tests, 835, 1092

Pipe line crossings, non-flammable substances, specifications, 645, 1077

Pipe lines and storage tanks, cathodic protection of, 337, 964

Pipe lines and wells, drinking water, sterilization of new and repaired, 344, 968

Preservatives, wood (See Wood Preservation)

President's address, 893

Program of annual meeting, 887

Property records and construction reports, 620, 925

R

Radioactive materials, detection of in filters of diesel locomotives, 344, 968

Rail, report and discussion, 783, 1086

—batter, causes and remedy, 814, 1091

—bonds, application of, 786, 1088

—continuous welded, fabrication, 776, 1054

—control cooled, failure investigation, 787, 1088

—corrugation—can it be prevented?, by C. H. Spaderna, 307

—engine burns, prevention and repair by welding, 883, 1094

—failure statistics, 794, 1091

—address by G. M. Magee, 1091

—head checks, 830, 1092

—heat treated and alloy, service tests, 831, 1092

open-hearth, specifications, revisions, 786, 1088

—record forms, 786, 1088

—sections, developments affecting, 858, 1092

—78-ft, joint gap measurements, 860, 1093

—joint impact effects, 865, 1093

—service tests, 859, 1093

—shelly spots, causes and prevention, 830, 1092

—investigation and tests, 850, 1092

Rail joints, lubrication tests, 735, 1070

Rails, control-cooled, investigation of failures in, address by R. E. Cramer, 1088

Receiving yards (See yards)

Records and Accounts, report and discussion, 579, 922

—bibliography, 582, 923

—budgetary procedures, 599, 924

—construction reports and property records, 620, 925

—ICC accounting classifications, revisions and interpretations, 641, 926

—office and drafting practices, 595, 923

—statistics, use of in railway engineering, 599, 924

—tabulating machines, use of in engineering department procedures, 620, 925

—valuation and depreciation, 638, 925

Regulatory bodies and courts, current developments, valuation accounting, 638, 925

Relocation of railroad embankment O'Hare field, Chicago, by R. B. Peck, 649, 1080

River Terminal Railway, steel truss span, tests on, 435, 993

Roadbed, construction and protection across reservoir areas, 648, 1080

—stabilization, 648, 1080

—electro-osmosis, by R. B. Peck, 658, 1080

Roadway, formation and protection, 648, 1080

Roadway and Ballast, report and discussion, 643, 1077

Rodgers, E. G., AAR weed control project, 662, 1079

Running time and total time between loading and unloading points of freight cars, comparison of, and methods of reducing total time, 321, 947

S

Sams, A. L., address, summary of report prepared by AAR Cal Sag committee in opposition to Cal Sag navigation project, 949

Sanitation, federal and state regulations, 336, 963

—waste disposal, 338, 965

Scales, electronic, track, 370, 929

—four-section motor truck, revisions, 369, 929

—weighing cars by the two-draft method, 369, 929

Schieferstein, R. H., AAR weed control project, 662, 1079

Scott, M. B., investigation of fatigue failures in structural members of ore bridges under service loadings, 175

Seaboard Air Line, bridge paint test, 557, 999

—timber stringer bridges, tests on, 435, 994

Secretary, executive, statement and report of, 898, 1105

Shops, diesel locomotive, facilities, 382, 1024

Sign, stop, for use by crossing watchmen, 329, 954

Southern, analysis of maintenance operations, 398, 1044

Spaderna, C. H., rail corrugation—can it be prevented?, 307

Speed on curves, 764, 1072

Speed, through turnouts, 767, 1072

Statistics, use of in railway engineering, 599, 924

Stephens, O. W., memoir, 1023

St. Louis–San Francisco, service test records of treated wood in bridges, 456, 1020

Students, booklet to stimulate interest in engineering career, 577, 970

—college, stimulate interest in science of transportation, 572, 969

—college, summer employment of and cooperative system of education, 574, 970

T

Tabulating machines, use of in engineering department procedures, 620, 925

—use of in preparing ICC returns, 620, 925

Tellers, report of, 890

Terminals, passenger, revision, 364, 928

—waterfront, 370, 930

Termites, destruction by, methods of prevention, 464, 1021

Tie pads, tests, 707, 1068

Tie plates, design of, 700, 1067
—hold-down fastenings for, including pads, 707, 1068
—service test on Cincinnati, New Orleans & Texas Pacific, 700, 1067
Tilman, D. W., panel discussion, college graduates, railroad employment versus other industry employment, 971
Timber—concrete composite decks, design of, 569, 977
Time, comparison of running and total of freight cars between loading and unloading points, methods of reducing total time, 321, 947
Ties, report and discussion, 441, 1055
—methods of retarding splitting and mechanical wear of, 1057
—panel discussion on, by L. C. Collister, L. P. Drew, C. S. Burt, P. D. Brentlinger, H. R. Duncan, L. W. Kistler, 1059
—renewal statistics and costs, 173, 1057
—renewing average of 100 per mile, economic size of force using on or off-track tampers, 430, 1050
—renewing, labor economy by use of proper equipment and organization, 423, 1046
—substitutes for wood, 1055
Tires and tubes, pneumatic, for work equipment, 490, 1038
Total time and running time between loading and unloading points of freight cars, comparison of, and methods of reducing total time, 321, 947
Track, report and discussion, 683, 1066
—committee on, highlights of work performed by, address, by C. J. Geyer, 1073
Track lining equipment, 514, 1041
Track maintenance, routine, comparative economy with limited size forces, and cycle, out-of-face with fully mechanized forces, 417, 1045
Track tools, plans and specifications, 685, 1066
Tracks, car repair, location and design, relation to classification yards, 374, 931
—engine servicing and facilities, location and design, relation to classification yards, 375, 931
Trackwork plans, 686, 1066
Trailers, highway, facilities for loading and unloading on railroad cars, 373, 930
—on flat cars, economics of service, 314, 945
—off-track, for housing maintenance forces, 519, 1042
Treasurer, statement and report, 899, 1120
Trucks, economy of handling maintenance of way gangs in, 424, 1048
Tunnels, ventilation, operation of diesel power, 660, 1078
Turnouts, speeds of trains through, revisions, 767, 1072

U

Union Pacific, service test records of treated ties, 450, 1020
Universities, cooperative system of education, 574, 970
—students, booklet to stimulate interest in engineering career, 577, 970
—study of transportation, stimulate greater interest in, 572, 969
—summer employment of students, 574, 970
U. S. Steel Corp., study of fatigue failures in ore bridges of, 196

V

Vegetation control (See also weed and brush control), 662, 1079

W

Warning devices to protect gangs against approaching trains, 504, 1040
Waste disposal, 338, 965
Waterways and Harbors, report and discussion, 377, 949
—bibliography, 377, 949
Water and oil servicing facilities for diesel locomotives, 342, 966
Water, Oil and Sanitation Service, report and discussion, 335, 963
Waterproofing, report and discussion, 437, 1017
—coatings, to prevent concrete deterioration, 439, 1018
—materials for, 438, 1017
Water treatment, cooling purposes, 339, 965
—diesel cooling systems, 337, 964
Weed and brush control, AAR research project, W. E. Loomis, E. G. Rodgers, L. O. Baker, R. H. Schieferstein, 662, 1079
Weighing freight cars by the two-draft method, 369, 929
Welding technique, tests on, for repair and serviceability of bolted rail crossing flangeway intersections, 768, 1073
Wells and pipe lines, drinking water, sterilization of new and repaired, 344, 968
Wilson, W. R., address, flood damage caused by hurricane Diane, 1009

Wood Bridges and Trestles, report and discussion, 565, 977

—fireproofing methods, fire-retardant paints, 566, 977

—timber-concrete composite decks, design of, 569, 977

Wood, treatment to make fire resistant, 468, 1020

Wood Preservation, report and discussion, 443, 1019

—chromated zinc arsenate, specification, 465, 1021

—destruction by marine organisms, method of prevention, 457, 1021

—fire resistant treatment, specifications, 468, 1022

—laminated timbers, 471, 1023

—new impregnants and procedures, increasing life of forest products, 464, 1021

—preservatives, revisions, 444, 1019

—service test records, 446, 1020

—termites, destruction by, methods of prevention, 464, 1021

—treatment specifications, revisions, 445, 1020

—volume correction factors for preservative salt solutions, 466, 1022

Work equipment, additional types desired, 518, 1041

—care and operation of in freezing weather, 505, 1040

—devices for warning forces of approaching trains, 504, 1040

—improvements to be made in existing, 488, 1038

—improvements to existing machines, 487, 1037

—new developments in, 474, 1037

—pneumatic tires and tubes for, 490, 1038

—storage batteries for, 496, 1039

—track lining equipment, 514, 1041

—trailers, off-track, for housing forces, 519, 1042

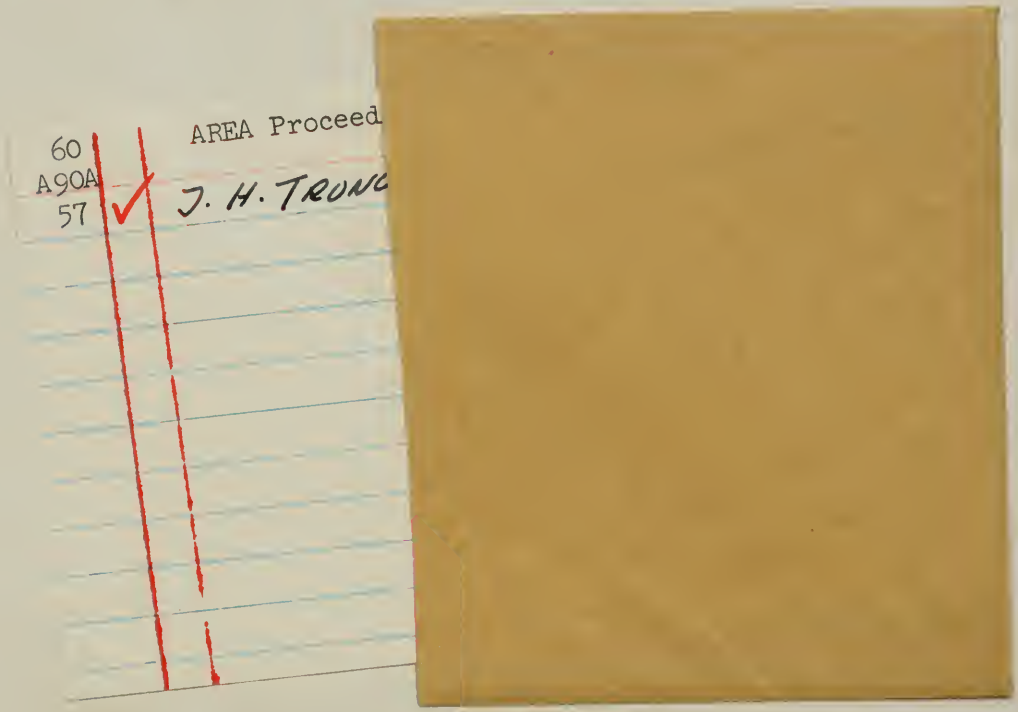
Wyly, L. T., fatigue failures in structural members of ore bridges under service loadings, 175

Y

Yager formula, revision, 314, 944

Yards and Terminals, report and discussion, 363, 928

Yards, receiving, classification and departure, track connections between, 365, 929


60
A90A
57
AREA Proceed
J. H. TRONC